A partial annotated bibliography of publications relevant to land, vegetation, and livestock management on arid lands, including the San Pedro Riparian National Conservation Area (SPRNCA)

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This bibliography is not an exhaustive literature search, but rather is a presentation of professional literature that will help interested parties understand the complexities of land and livestock management on the SPRNCA and critically examine the proposed actions and alternatives in the Bureau of Land Management's 2018 Draft Resource Management Plan for the SPRNCA.

Five especially relevant publications present published data collected on or near the SPRNCA and should be read in full:

Coalition for Sonoran Desert Protection. 2001. Livestock grazing and the Sonoran Conservation Plan.

Krueper, D. J. 1993. Effects of livestock management on Southwestern riparian ecosystems. Bureau of Land Management, San Pedro Riparian National Conservation Area.

Krueper, D., J. Bart, and T Rich. 2003. Response of vegetation and breeding birds to the removal of cattle on the San Pedro River, Arizona (USA). Conservation Biology, Vol. 17, No. 2: pages 607-615.

National Riparian Service Team. 2012. Riparian Conditions Along the San Pedro River: Proper Functioning Condition Riparian Assessment Report. USDI, NRST, BLM, USDA, NRCS.

Stromberg, J.C. and Barbara Tellman. 2009. Ecology and Conservation of the San Pedro River. The University of Arizona Press.529 pp.

The information following the literature citations is either an abstract included in the publication by the author or an introduction or summary that appeared in the publication.

Annotated bibliography:

Allington, G.R.H.and T. J. Valone. 2011. Long-term livestock exclusion in an arid grassland alters vegetation and soil. Rangeland Ecology Management 64(4):424-428.

Changes in soil and vegetation due to livestock grazing are occurring in arid lands throughout the world. The most extreme cases result in desertification, which is seen as largely irreversible, because of altered soil properties. To understand better how long-term livestock removal affects soil properties and vegetation, we compared water-infiltration rates, soil bulk density, and perennial grass cover inside and outside a long-term livestock exclosure in an arid grassland site in southeastern Arizona, United States. The site had not been desertified at the time of this study. Exclusion of livestock for 40 yr was associated with lower bulk density and higher water infiltration in both the dry and wet seasons. Perennial grass cover was higher and two native grasses, Eragrostis intermedia and Bouteloua hirsuta were significantly more common (P , 0.05) in the ungrazed area. These findings parallel our results from a desertified site and suggest that

changes in soil physical properties associated with long-term livestock removal are not an artifact of desertification and can take place in a system that has remained in a grassland state. Our data suggest that, although significant changes in species composition have occurred, this grassland is relatively resilient to substantial changes in soil physical properties.

Bahre, C.J. and M.L. Shelton. 1993. Historic Vegetation Change, Mesquite Increases, and Climate in Southeastern Arizona. Journal of Biogeography 20: 489-504.

Except possibly for increases in woody xerophytes such as mesquite, all of the identified long-term vegetation changes appear to be of anthropogenic origin. Mesquite increases, however, are irregular, show no clear relation to precipitation variations, and are most likely the result of livestock grazing and/or fire exclusion.

Bahre, C.J. and M.L. Shelton. 1996.

Rangeland destruction: Cattle and drought in southeastern Arizona at the turn of the century. J. of the Southwest 38 (1): 1-22. Recurring droughts and overstocking the open range led to huge cattle die-offs and degraded range conditions during the droughts of 1891-93 and 1898-1904. Since then, because of more efficient transportation, increased supplemental feeding, greater water development, and improved cattle marketing, droughts no longer exact major cattle die-offs on the range.

Belsky, A.J., A.Matzke, S. Uselman. 1999. Survey of livestock influences on stream and riparian ecosystems in the western United States. Journal of Soil and Water Conservation, Vol. 54, pp. 410-431.

This paper summarizes the major effects of livestock grazing on stream and riparian ecosystems in the arid West. We focused primarily on results from peer-reviewed, experimental studies, and secondarily on comparative studies of grazed vs. naturally or historically protected areas. Results were summarized in tabular form. Livestock grazing was found to negatively affect water quality and seasonal quantity, stream channel morphology, hydrology, riparian zone soils, instream and streambank vegetation, and aquatic and riparian wildlife. No positive environmental impacts were found. Livestock were also found to cause negative impacts at the landscape and regional levels. Although it is sometimes difficult to draw generalizations from the many studies, due in part to differences in methodology and environmental variability among study sites, most recent scientific studies document that livestock grazing continues to be detrimental to stream and riparian ecosystems in the West.

Bock, C.E., J.H. Bock, W.R. Kenney, V.M. Hawthorne. 1984. Responses of Birds, Rodents, and Vegetation to Livestock Exclosure in a Semidesert Grassland Site. J.Range Management 37:239-242.

In 1981-82, a protected upland site supported 45% more grass cover, a comparatively mixed group of grass species, and 4 times as many shrubs as an adjacent grazed site. The grazed area supported a significantly higher number of birds in summer, while numbers did not differ in winter. Rodents were significantly more abundant inside the protected area.

Bock, C.E., J.H.Bock. 1993. Cover of Perennial Grasses in Southeastern Arizona in Relation to Livestock Grazing. Conservation Biology 7: 371-377.

Total grass canopy cover was greater on ungrazed grasslands. Eight bunchgrass species also grew taller on ungrazed areas -- the three tallest species (Bouteloua curtipendula, Bothriochloa barbinodis, and Eragrostis intermedia) showed the greatest increase on ungrazed areas. Two short stoloniferous species (Hilaria belangeri and Bouteloua eriopoda) were the only taxa substantially more abundant on grazed areas. Bouteloua gracilis, the most abundant grass in the region, showed an intermediate response to release from grazing. Livestock grazing appeared to be an exotic ecological force in these southwestern grasslands, and one destructive of certain components of the native flora and fauna.

Bock, C.E., J.H. Bock. 1993. Effects of Long Term Livestock Exclusion in a Semiarid Grassland. Pp.123-133 in (P.G.Rowlands, C.Riper III, and M.K.Sogge, editors) Proceedings of the First Biennial Conference on Research in Colorado Plateau National Parks. National Park Service, Center for Colorado Plateau Studies, Northern AZ U., Flagstaff.

Canopy cover of upland perennial grasses was 61% on the Appleton-Whittell Research Ranch (AWRR) and 41% on adjacent cattle ranches. Peak fall densities of grasshoppers were three times higher on grazed lands. The bunch grass lizard was the most abundant reptile on AWRR and virtually absent on adjacent ranches. Cottonrats, harvest mice, and hispid pocket mice were the most common rodents in ungrazed habitat, whereas deer mice and kangaroo rat predominated in grazed areas. Montezuma quail, Cassin's sparrows, Botteri's sparrows, and grasshopper sparrows were common breeding birds on AWRR, whereas scaled quail, horned larks, and lark sparrows were the most abundant nesting birds on grazed lands.

Bock, Carl E. and Jane H. Bock. 2000. Response of Winter Birds to Drought and Short- duration Grazing in Southeastern Arizona. P. 5 in (Linda Kennedy and Stephanie Seltzer, editors) Audubon Research Ranch 2000. National Audubon Society Appleton-Whittell Research Ranch. Elgin AZ. 84 pgs.

Abstract reports high-density short-duration rotational grazing, coupled with a drought, left the land in a substantially denuded condition through two winters, and this in turn negatively impacted a variety of resident and migratory birds dependent on ground cover and seed production for over-winter survival.

Bock, Carl E. and Jane H. Bock. 2000. Vegetative Changes in a Grass/Shrubland after Fifteen Years Without Disturbance. P. 8 in (Linda Kennedy and Stephanie Seltzer, editors) Audubon Research Ranch 2000. National Audubon Society Appleton-Whittell Research Ranch. Elgin AZ. 84 pgs.

Preliminary results show that from 1985-2000 total shrub densities have decreased on Bald Hill on the Appleton-Whittell Research Ranch and that exotic lovegrasses are spreading significantly but slowly, despite the absence of fire, grazing, or other disturbance.

Bock, Jane H., Carl E. Bock. 2002. Wildflowers, Weeds, Precipitation, and Livestock Grazing in an Arizona Grassland. Abstract: Ecological Society of America 87th Annual Meeting/Society for Ecological Restoration 14th Annual International Conference. August 4-9, Tucson, AZ. Pg.79.

In summer of 2001 when winter precipitation had exceeded 25 cm., wildflower cover equaled that of native grasses and was significantly lower on livestock-grazed areas than on ungrazed native grassland, and much lower still in plantations of exotic African lovegrasses. Results suggest the important positive influence of winter rain on many of the wildflower species, and the negative effects of grazing and exotics.

Bock, C., J. Bock, L. Kennedy, and Z. Jones. 2007a. Spread of non-native grasses into grazed versus ungrazed desert grasslands. Journal of Arid Environments 71:229–235.

Indications are that (1) protection from grazing reduced the rate of exotic invasions into native grasslands; (2) areas deliberately planted with the exotics developed into near monocultures even under livestock exclusion; (3) livestock grazing is an exogenous disturbance to which exotics are better adapted than most native grasses.

Brady, W.W, M.R. Stromberg, E.F. Aldon, C.D. Bonham, S.H. Henry. 1989. Response of a Semidesert Grassland to 16 Years of Rest from Grazing. J. Range Management 42:284-288.

Long-term response to release from grazing included both increases in types of grasses and significant increases in canopy cover for midgrass, shortgrass, shrub, and forb plant groups. Total vegetation cover was not significantly different on the grazed and ungrazed areas, but cover of midgrasses was significantly different (this difference due to increased cover of plains lovegrass on ungrazed pasture. Data do not support the hypothesis that continued animal impact is necessary to prevent ecosystem deterioration.

Bunting, Daniel P. 2012. Riparian Restoration and Management of Arid and Semiarid watersheds. PhD Thesis for the University of Arizona School of Natural Resources and the Environment.

Riparian ecosystems are valued for ecosystem services which have impacts on the well-being of humans and the environment. Anthropogenic disturbances along rivers in arid and semiarid regions have altered historical flow regimes and compromised their integrity. Many rivers are hydroecologically deteriorated, have diminished native riparian forests, and are pressured for their water supplies.

My first study is founded on the premise that river restoration has increased exponentially with little documentation on effectiveness. We designed a conference to discuss lessons learned from past restoration activities to benefit future efforts. Participants, who included scientists, managers, and practitioners, agreed that creating measureable objectives with subsequent monitoring is essential for quantifying success and employing adaptive management. Attendees stated that current projects are local and have limited funding and time, whereas future efforts must have longer funding cycles, larger timeframes, should contribute to regional goals, and address factors responsible for ecological decline. Bridging gaps among science, management, and policy in the 21st century is a key component to success.

My second study focused on the benefits of long-term monitoring of local riparian restoration. Many efforts include revegetation components to re-establish native cottonwood-willow communities, but do not address how high-density establishment impacts vegetation dynamics and sustainability. Over five years, we documented significantly higher growth rates, lower mortality, and higher cover in cottonwood compared to non-native tamarisk. Cottonwood height, diameter at breast height, growth rates, and foliar volumes were reduced at higher densities. Herbaceous species decreased every year but native shrubs volunteered after two years resulting in a reduction of overall plant diversity from 2007-2009 with a slight increase from 2009-2011. My third study focused on improving basin-scale evapotranspiration (ET), a large component of the water budget, to better inform water resource allocation.

Coalition for Sonoran Desert Protection. 2001. Livestock grazing and the Sonoran Conservation Plan.

Most of the peer-reviewed scientific literature available does not support conservation benefits of livestock grazing. The draft preliminary Plan, for example, emphasizes the use of ranch land as a boundary for urban growth. Ranches may well provide valuable open space. But where livestock grazing contributes to degradation of native ecological conditions and imperilment of species, other means of urban growth control must be utilized, and grazing must be eliminated from the most ecologically sensitive areas. The Coalition acknowledges and encourages the efforts of ranchers to reduce negative effects of livestock grazing and to restore extirpated wildlife. But these cases are exceptions. The compatibility of livestock grazing with conservation of native Sonoran desert ecological conditions and vulnerable species remains unproven.

Gebhardt, K., D. Prichard, E. Crowley, and M. Stevenson. 2005. Riparian area management: Riparian and wetland classification review and application. Technical Reference 1737-21. U.S. Department of the Interior, Bureau of Land Management, Denver, CO. BLM/ST/ST-05/002+1737. 26 pp.

“Classifying riparian vegetation therefore requires a full understanding of species distribution and succession, in relation to environmental parameters and disturbance factors over a large area. Watershed and ecoregion frameworks are complementary. Watersheds provide the framework for determining the land/water associations, and ecoregions provide the framework for extrapolating and reporting this information. As with any procedure, misapplication is likely to occur if the users rely solely on the classification tool or its products and not on the underlying science behind the classification. Users must always place the science in front of the classification and not the other way around. Riparian and wetland systems are dynamic. Mapping and classification often produce only a snapshot that does not represent the dynamics of the system.

Hall, John A., Stephanie Weinstein, Cheryl L. McIntyre. 2005. The Impacts of Livestock Grazing in the Sonoran Desert: A Literature Review and Synthesis. The Nature Conservancy, Phoenix Field Office. Federal Cooperative Agreement No. AAA-02-0005, Task Order AAF-02-0001. 298 pgs.

At the request of the BLM, The Nature Conservancy reviewed the literature regarding: (1) the impact of cattle on natural and cultural resources in desert ecosystems, (2) the implications of different grazing management strategies, (3) Sonoran Desert plant community dynamics. The literature does document that livestock grazing can cause adverse impacts, but does not provide

sufficient information regarding thresholds of grazing intensity and effect on the ecosystem. Compared to more productive rangelands, both domestic livestock grazing impacts and grazing management strategies are poorly documented for the Sonoran Desert. No currently described approach, including continuous grazing and each of the specialized grazing systems, seems completely applicable to the Sonoran Desert. The study of literature also includes looking at the effects of grazing on plant communities, Saguaro recruitment and survival, other plant species, soils and biological soil crusts, wildlife, and cultural sites.

Hereford, R. 1993. Entrenchment and widening of the upper San Pedro River, Arizona. U.S. Geological Survey. Special Paper 282. 46 p.

A portion of Arizona's San Pedro River is managed as a National Riparian Conservation Area but is potentially affected by ground-water withdrawals beyond the conservation area borders. We applied an assessment model to the Conservation Area as a basis for monitoring long-term changes in riparian ecosystem condition resulting from changes in river water availability, and collected multi-year data on a subset of the most sensitive bioindicators. The assessment model is based on nine vegetation bioindicators that are sensitive to changes in surface water or ground water. Site index scores allow for placement into one of three condition classes, each reflecting particular ranges for site hydrology and vegetation structure. We collected the bioindicator data at 26 sites distributed among 14 reaches that had similar stream flow hydrology (spatial flow intermittency) and geomorphology (channel sinuosity, flood-plain width). Overall, 39% of the riparian corridor fell within condition class 3 (the wettest condition), 55% in condition class 2, and 6% in the driest condition class. Condition class 3 reaches have high cover of herbaceous wetland plants (e.g., Juncus and Schoenoplectus spp.) along the perennial stream channel and dense, multi-aged Populus-Salix woodlands in the flood plain, sustained by shallow ground water in the stream alluvium. In condition class 2, intermittent stream flows result in low cover of streamside wetland herbs, but Populus-Salixremain abundant in the flood plain. Perennial wetland plants are absent from condition class 1, reflecting highly intermittent stream flows; the flood plain is vegetated by Tamarixa small tree that tolerates the deep and fluctuating ground water levels that typify this reach type. Abundance of herbaceous wetland plants and growth rate of Salix gooddingii varied between years with different stream flow rates, indicating utility of these measures for tracking short-term responses to hydrologic change. Repeat measurement of all bioindicators will indicate long-term trends in hydro-vegetational condition.

Jones, A. 2000. Effects of cattle grazing on North American arid ecosystems: A quantitative review. Western North American Naturalist 60:155-164.

A quantitative review was conducted of the effects of cattle grazing in arid systems on 16 response vari- ables ranging from soil bulk density to total vegetative cover to rodent species diversity. Various studies from North American arid environments that used similar measures for assessing grazing effects on the same response variables were used for the review; each study was assigned to serve as a single data point in paired comparisons of grazed versus ungrazed sites. All analyses tested the 1-tailed null hypothesis that grazing has no effect on the measured variable. Eleven of 16 analyses (69%) revealed significant detrimental effects of cattle grazing, suggesting that cattle can have a negative impact on North American xeric ecosystems. Soil-related variables were most negatively impacted by grazing (3 of 4 categories tested were significantly impacted), followed by litter cover and biomass (2 of 2 categories tested), and rodent diversity and richness

(2 of 2 categories tested). Vegetative variables showed more variability in terms of quantifi- able grazing effects, with 4 of 8 categories testing significantly. Overall, these findings could shed light on which suites of variables may be effectively used by land managers to measure ecosystem integrity and rangeland health in grazed systems.

Kaltenecker, J. H., and M. C. Wicklow-Howard. 1999. Biological soil crusts: Natural barriers to Bromus tectorum L. establishment in the northern Great Basin, USA. VIth International Rangeland Congress — Proceedings, Townsville 109-111.

In arid and semi-arid lands throughout the world, vegetation cover is often sparse or absent. Nevertheless, in open spaces between the higher plants, the soil surface is generally not bare of autotrophic life, but covered by a community of highly specialized organisms (Fig. 1.1). These communities are referred to as biological soil crusts, or cryptogamic, cryptobiotic, microbiotic, or microphytic soil crusts (Harper and Marble 1988; West 1990). Biological soil crusts are a complex mosaic of cyanobacteria, green algae, lichens, mosses, microfungi, and other bacteria. Cyanobacterial and microfungal filaments weave through the top few millimeters of soil, gluing loose particles together and forming a matrix that stabilizes and protects soil surfaces from erosive forces (Cameron 1966; Friedmann and Galun 1974; Friedmann and Ocampo-Paus 1976; Belnap and Gardner 1993). These crusts occur in all hot, cool, and cold arid and semi-arid regions. They may constitute up to 70% of the living cover in some plant communities (Belnap 1994). However, biological soil crusts have only recently been recognized as having a major influence on terrestrial ecosystems.

Kelt, D. A., and T. J. Valone. 1995. Effects of grazing on the abundance and diversity of annual plants in Chihuahuan desert scrub habitat. Oecologia Berlin 103:191-195.

We assess the impact of release from cattle grazing on the abundance and diversity of both winter and summer annual plant communities at an upper Chihuahuan Desert scrub site in south-eastern Arizona. In contrast to previous studies, we found that removal of herbivores (cattle) had little impact on ephemeral plant assemblages at our site. The total number of summer annual individuals per quadrat did not differ significantly, but there were significantly more winter annual plants on ungrazed quadrats. The number of species per quadrat, however, did not differ significantly between sites exposed to, or protected from, grazing in either season. Of 79 annual species recorded (34 in winter, 45 in summer), only 2 species, 1 in each season, responded significantly to the removal of cattle: Stephanomeria exigua and Polygala tweedyiwere more abundant on ungrazed plots. Three additional species, Eriastrum diffusum and Cryptantha micrantha in winter, and Mollugo cerviana (summer), approached statistical significance. Differences in the effect of cattle grazing on annual plants between our results and those at other sites in the arid southwest most likely reflect differences in the speed of response by annuals in different areas. Comparisons of this with other studies underscores recent calls for studies at broader spatial and greater temporal scales.

Klotz, Jason, and Aregai Tecle. 2015. Restoring the Water Quality of the San Pedro River Watershed. Hydrology and Water Resources in Arizona and the Southwest. Arizona-Nevada Academy of Science.

This paper is concerned with restoring the quality of water in some portions of the San Pedro River. There are high concentrations of bacteria in some parts of the San Pedro River. Our aim is to find ways of improving the situation. Specifically, there are two objectives in the study. The first one attempts to identify the possible sources of the bacterial contamination and assess its trends within the watershed. The second objective is to determine appropriate methods of restoring the water quality. The main water quality problem is nonpoint source pollution, which enters the stream and moves along with it. The magnitude of the problem is affected by the size and duration of the streamflow, which brings bacteria-laden sediment. The amount of sediment brought into the system is large during the monsoonal events. At this time, the streamflow becomes highly turbid in response to the organic and inorganic sediments entering the system. Based on research done for this paper, the amount of bacterial concentration is strongly related to turbidity. Best management practices (BMPs) have been designed and implemented to restore the water quality problem in the area. The BMP's consist of actions such as monitoring, educational outreach, proper signage, and other range/watershed related improvement practices. Other issues that contribute to the increasing amount of bacteria that are briefly addressed in this paper are bank and gully erosion, flood control, and surface water and streamflow issues that occur on the stream headwaters.

Krueper, D. J. 1993. Effects of livestock management on Southwestern riparian ecosystems. Bureau of Land Management, San Pedro Riparian National Conservation Area.

Riparian habitats historically constituted 1% of the landmass in western North America. Within the past 100 years, an estimated 95% of this habitat has been altered, degraded or destroyed due to a wide variety of land use practices such as river channelization, clearing for agriculture, livestock grazing, water impoundments and urbanization. Many authors now concur that the single most important land management practice impacting western riparian ecosystems has been unmanaged domestic livestock grazing. Over 70% of the western United States is currently being grazed by livestock in habitats ranging from sea level to alpine meadows. Unwise grazing practices have been shown to negatively affect Southwestern riparian vegetative com- position, ecosystem function, and ecosystem structure. This has resulted in negative impacts on native wildlife populations including insects, fish, reptiles, amphibians, birds, and mammals. Negative impacts due largely from over a century of heavy domestic livestock utilization in riparian ecosystems has resulted in the decline of many wildlife populations. Studies have shown that up to 70% of avian species in the desert Southwest depend upon riparian habitats for survival at some stage of their life. Over forty percent of Arizona’s state-listed bird species are considered to be riparian obligate species. Ninety percent of Arizona’s native fish species are now extinct, extirpated, or Federally or state listed. Many other vertebrate species have declined in recent years due to alteration of riparian habitats, and may soon be considered for Federal listing. To prevent future listings and to reverse population declines of sensitive wildlife species, land management agencies need to implement appropriate practices within riparian ecosystems.

Krueper, D., J. Bart, and T Rich. 2003. Response of vegetation and breeding birds to the removal of cattle on the San Pedro River, Arizona (USA). Conservation Biology, Vol. 17, No. 2: pages 607-615.

A before-and-after study from 1986-1990 (Krueper et al. 2003) found that more birds were detected in an area of riparian, mesquite and Chihuahuan desert-scrub in Arizona, USA, after the removal of cattle and the onset of a grazing moratorium in 1988 (average of 221 birds detected/km of transect in 1990 vs. 103 birds/km for 1986). Detections increased for 42 species,

26 significantly, and decreased for 19 species, eight significantly. Only four species in the study showed similar trends in regional Breeding Bird Surveys. Insectivores, granivores, midstory species, upperstory species and riparian species were most likely to increase, and migrants tended to show greater increases than residents. Chihuahuan desert-scrub species showed the smallest increases and were most likely to decline, possibly because the Chihuahuan scrub changed the least with the grazing moratorium. Surveys were conducted three times a month, every month over the study period.

La Porte, Ariana. 2017. Masters Thesis for University of Arizona School of Natural Resources and the Environment. Gray Hawk Expansion in the San Pedro River Valley: Diet, Habitat, and Landscape Change.

We found that that gray hawks used a wider variety of vegetation types, such as nest trees surrounded by grasslands, and consumed a wider variety of prey than they did in the 1990s, and that productivity remained constant over time. Like many populations at the edge of their range, the gray hawks that initially settled in the San Pedro River valley likely had access to only a portion of the resources that are common at the center of the species' range, and therefore appeared to have a narrower set of diet and habitat requirements than the species as a whole. Areas that are currently being used by gray hawks for nesting (e.g., nest trees surrounded by grasslands) were likely unsuitable in the 1990's because they were then being used for agriculture and grazing. The two chapters of this thesis will be submitted to journals for publication and therefore contain overlapping information.

Hoorman, J. and J. McCutcheon. 2012. Negative effects of livestock grazing riparian areas. Ohio State University Extension Fact Sheet.

The current environmental focus on controlling nonpoint pollution to protect our surface water has led to the discussion of management of riparian areas. The Environmental Protection Agency states that agriculture has a greater impact on stream and river contamination than any other nonpoint source. Grazing, particularly improper grazing of riparian areas can contribute to nonpoint source pollution. Negative impacts downstream include the contamination of drinking water supplies (55% of Ohios drinking water comes from surface water (Brown, 1994)), eutrophication of Lake Erie (Richards et al., 2002), and hypoxia in the Gulf of Mexico (Rabalais et al., 2001). This series of fact sheets looks at the issues of livestock and streams and what livestock producers can do to protect this precious resource. Before we discuss managing grazing livestock to decrease nonpoint pollution, it would be helpful to review the damage livestock can do to riparian areas and surface water. One cannot discuss the effects on streams by grazing livestock without recognizing the interwoven and connected nature of watersheds, riparian zones, streams, and watershed activities. Activities affecting watersheds or riparian zones also affect stream ecosystems directly, indirectly, and cumulatively. Although this series of fact sheets primarily focuses on the riparian areas, it is understated that mismanagement of the land resources in the watershed can have as big an impact on surface water.

Mack, R. N., and J. N. Thompson. 1982. Evolution in steppe with few large, hoofed animals. The American Naturalist 119:757-772.

National Riparian Service Team. 2012. Riparian Conditions Along the San Pedro River: Proper Functioning Condition Riparian Assessment Report. USDI, NRST, BLM, USDA, NRCS.

The assessment findings provide evidence that the physical function and ecological health of the San Pedro River through the SPRNCA has improved dramatically since designation, largely due to the 1989 decision to end permitted livestock grazing along the river. Although recovery may have been possible with managed grazing, relief from grazing pressure has allowed development of riparian vegetation and channel characteristics that greatly improve the function and sustainability of the San Pedro River. Continued recovery in all reaches is necessary to meet Congressional direction, but significant positive changes have occurred already. Of the approximately 51 miles assessed, 27.4 miles (54%) were rated as Proper Functioning Condition, and the remaining 23.4 miles (46%) rated as Functional at Risk (FAR). The Functional at Risk reaches were further assigned apparent trend: 8.9 miles showed an upward trend, 10.3 miles showed a not apparent trend, and 4.2 miles (the northernmost reach below St. David's diversion) showed a downward trend.

Reach-specific assessment findings, issues and management considerations are discussed in detail within the report. For reaches rated Functional at Risk with either a downward or not apparent trend, the NRST recommends the establishment of a monitoring strategy to measure change over time. Additionally, since St. David is the only reach rated as Functional at Risk (with a downward trend), it requires immediate management action be taken to eliminate those stressors that are within management control. The main impacts limiting the ability of St. David reach to achieve Proper Functioning Condition are the St. David's diversion, livestock grazing and off-highway vehicle use. The latter two uses are currently unauthorized and within BLM management purview to address.

One of the major decisions made in 1989 through the SPRNCA's original management plan(s) was to end permitted livestock grazing in areas along the river. As previously noted, this has allowed development of riparian vegetation and channel characteristics that greatly improve the function and sustainability of the San Pedro River. A key finding of this assessment, however, is that while the BLM made efforts to eliminate trespass livestock in the SPRNCA, more needs to be done and State Office support is needed. Livestock use is, to some degree, retarding recovery of sections of the river; unauthorized grazing was found all along the river, but the detrimental impacts were more visible in localized areas within certain reaches.

Trespass livestock grazing in the river corridor must be eliminated to provide the maximum opportunity for continued improvement and evolution of the river. Furthermore, Proper Functioning Condition assessment findings indicate that the riparian corridor and river are not yet to a point, overall, that livestock grazing could be permitted along the San Pedro River without retarding improvement or even causing impairment. These geomorphic changes to floodplain and channel have been most evident since 1989, when BLM ceased authorized livestock grazing along the San Pedro River. Vegetation expression following livestock removal improved trapping of suspended sediment.

Livestock and off-highway vehicle use, on the other hand, do fall under the BLM's management purview, and neither use is currently authorized. Elimination of these unauthorized uses would be a major step in helping recovery of St David reach and are given increased importance since that is the only management action that can be taken directly by the BLM to improve condition of the reach.

It was noted that much of the herbaceous vegetation is relatively young and indicates recovery since livestock removal about 25 years ago. Bulrush in particular appears abundant in many portions of the reach, and is forming community types that will be very important over time for stable bank and channel development. After livestock were removed from the San Pedro River within SPRNCA in 1989, riparian vegetation has expanded tremendously. This vegetation has trapped sediment during high flows, which in turn has built stream banks and formed a narrower,

deeper channel. Continuing evolution of the channel will likely occur in timeframes measured in decades before levels of dynamic stability are attained similar to those that occurred prior to entrenchment in the late 19th century.

Nguyen, 2015. Multiscale remote sensing analysis to monitor riparian upland semiarid vegetation. PhD thesis for University of Arizona Department of Soil, Water and Environmental Science.

"…the site has been heavily grazed by livestock, reducing plant cover and LAI. I worked with the authors use livestock exclosures and revegetation plots to determine the effects of grazing on LAI, fc and ET, then projected the findings over the whole site using multi-platform remote sensing methods. We show that ET is approximately equal to annual precipitation at the site, but when ATCA and SAVE are protected from grazing they can develop high fc and LAI values, and ET can exceed annual precipitation, with the excess coming from groundwater discharge. Therefore, control of grazing could be an effective method to slow migration of contaminants at this and similar sites in the western U.S.

Sisk, Thomas, Timothy Crews and Lauren Golten. 2000. Effects of Livestock Management on Ecosystem Productivity and Biological Diversity in Southwestern Grasslands. P. 31 in (Linda Kennedy and Stephanie Seltzer, editors) Audubon Research Ranch 2000. National Audubon Society Appleton-Whittell Research Ranch. Elgin AZ. 84 pgs.

Results from a pilot study done after two consecutive drought years showed that aboveground, net primary productivity was significantly higher at the ungrazed site (the Appleton-Whittell Research Ranch) compared to the traditional and HRM managed ranches whereas plant species diversity did not vary significantly as a function of livestock management. The aim of a proposed study is to bridge the existing gulf between research science, ranchers, other land managers, and the public.

Smith, Hobart M., Carl E. Bock and J.H. Bock. 2000. The Effect of Livestock Grazing upon Sleven's bunch Grass Lizard. P. 44 in (Linda Kennedy and Stephanie Seltzer, editors) Audubon Research Ranch 2000. National Audubon Society Appleton-Whittell Research Ranch. Elgin AZ. 84 pgs.

More Slevin's bunch grass lizards were found on the Appleton-Whittell Research Ranch than on adjacent grazed land. Results indicate the previous assumption that this species is limited to higher elevations, 7000-10,000 feet, was due to the effect of grazing, rather than elevation.

Stromberg, J.C. and Barbara Tellman. 2009. Ecology and Conservation of the San Pedro River. The University of Arizona Press.529 pp.

This book provides an extensive knowledge base on all aspects of the San Pedro, from flora and fauna to hydrology and human use to preservation. It describes the ecological patterns and processes of this aridland river and explores both the ongoing science-driven efforts by nonprofit groups and government agencies to sustain and restore its riparian ecosystems and the science that supports these management decisions.

An interdisciplinary team of fifty-seven contributors—biologists, ecologists, geomorphologists,

historians, hydrologists, lawyers, political scientists—weave together threads from their diverse perspectives to reveal the processes that shape the past, present, and future of the San Pedro's riparian and aquatic ecosystems. They review the biological communities of the San Pedro and the stream hydrology and geomorphology that affect its riparian biota. They then look at conservation and management challenges along three sections of the San Pedro, from its headwaters in Mexico to its confluence with the Gila River, describing legal and policy issues and their interface with science; activities related to mitigation, conservation, and restoration; and a prognosis of the potential for sustaining the basin's riparian system.

Tellman, Barbara, Deborah Finch, Carl Edminster and Robert Hamre, Eds. 19. The Future of Arid Grasslands: Identifying Issues, Seeking Solutions. Proceedings of October 9-13, 1996 conference. Rocky Mountain Research Station. Fort Collins CO. 392 pgs.

Bock records the presentations of 74 representatives from private ranchers and other private landowners, non-profit groups (such as The Nature Conservancy and NAS-TRR), governmental agencies with responsibility for grassland management, environmental advocates, economists, scientists, and others who were brought together to try and resolve conflicts in non-confrontational ways. The emphasis was on practical, hands-on management methods under a variety of techniques.

Tucson Audubon Society, Arizona Important Bird Areas Program. Riparian Habitat Mangement in Arizona: A guide for private landowners seeking to preserve habitat for birds and other wildlife.

Important Bird Areas are sites that provide essential habitat for one or more species of birds. Sites can be those used by birds for breeding (nesting), wintering, or during migration. They may be public or private lands, or a combination of both, and they may or may not be protected by legal definition. The IBA program is voluntary, participatory, inclusive and science-based. Sites in Arizona are identified as IBAs by the Arizona IBA Science Committee. Bunch Grassland: This vegetation community occurs within the valley bottom floodplains, typically adjacent to cottonwood/willow, in lower swales or a depressed basin, where mesquite, oak, or desert scrub, may be present on higher ground. This community can also surround cienega or riverine marsh communities. Grasses grow in clumps, and can easily reach 6 feet and higher. Grassland sparrows and buntings depend on this vegetative community, as do numerous small mammal and reptile species. Dry Desert Washes: Lined by the most lush vegetation in an arid landscape, the taller and more robust specimens of desert species thrive along desert washes.

Desert willow, desert and net-leaf hackberry, blue palo verde, and ironwood reach their greatest development in this community. The flowers and fruit are produced in abundance by the above species, and are a magnet to desert wildlife and insects. Trees and shrubs on the uppermost river or stream terrace, for example the mesquite/hackberry bosque, tall in height, with spreading crowns, with numerous understory shrubs, and a ground cover of mostly native grasses and forbs are important wildlife habitat. Keeping vehicles out of protected areas will promote the good soil conditions necessary for native tree establishment. This action also will prevent soil erosion, desiccation, and compaction. It will also preclude the introduction of non-native plants, many of whose seeds are transported from place to place on car tires. Leave old, large trees and branches (tree trunks/branches > 12 in.) even if they are dead, because they provide critical places for cavity-nesting birds, mammals, and reptiles to raise their young. In regard to birds, protecting forest tracts of large mesquite will benefit Gray Hawk foraging habitat, and foraging and nesting

habitat for Elf Owl, Yellow-billed Cuckoo, Bewick's Wren, Ladder-backed Woodpecker, Ash-throated Flycatcher, Phainopepla, Verdin, Black-tailed Gnatcatcher and many others.

Wuerthner, George, Mollie Matteson. 2002. Welfare Ranching: The Subsidized Destruction of the American West. Foundation Ecology, Sausalito, CA. 343 pgs.

With photographs and essays, this book shows not only cases of overgrazing on both private and public lands but also the subtle changes that signal ecological disruption on a massive scale. It explains the cultural and historical causes of the wasting of the West and offers a vision of the renewal possible if citizens ask that their government shift land management priorities to serving the public and natural good, rather than facilitating private gain. It points the way to the greatest opportunity yet remaining: that of ending public lands livestock grazing, for ecological restoration and wildlife protection in this country.

Wolfson, L. and T. Harrigan. 2010. Cows, streams, and E. Coli: What everyone needs to know. Michigan State University Extension. (www.animalagteam.msu.edu).

Contamination of water by bacteria is one of the leading causes of impairment in U.S. surface waters. E. coli (E. coli 0157;H7) as well as viruses and some protozoans are referred to as pathogens. Most are found in the gastrointestinal tract of humans and other warm-blooded animals and are shed in the feces. Significant sources of fecal material to lakes and streams include wastewater discharge, storm runoff, and manure runoff. The fecal material in these sources comes from warm-blooded animals including humans, pets, wildlife, and farm animals. One study found that grass buffer strips were 99% effective at capturing soil they were only 74% effective at capturing fecal material. Prohibiting livestock from accessing streams, steep sloping areas near water bodies, and other surface waters is an effective way to reduce water pollution.

Zaimes, G, editor. 2007. Understanding Arizona's riparian areas. The University of Arizona, Arizona Cooperative Extension. AZ 1432.

The three main characteristics that define riparian area ecosystems are hydrology, soils and vegetation. These areas have water-soil-vegetation habitats that reflect the influence of additional moisture as compared to their adjacent terrestrial uplands. Aquatic ecosystems are in water either year- round or for long periods of time. Terrestrial ecosystems are on land. Riparian areas are not as dry as upland terrestrial ecosystems but not as wet as aquatic ecosystems. These areas are the transition zones or ecotones and have characteristics of both aquatic and upland terrestrial ecosystems. This is reflected with the presence of a larger number and more diverse species. Another characteristic of an ecotone is the active interactions that take place between two or more of its adjacent ecosystems, and leads to the appearance of mechanisms that do not exist in either of the adjacent ecosystems. The following definitions of "riparian ecosystems" are provided:

U.S. Environmental Protection Agency: "Riparian areas are vegetated ecosystems along a water body through which energy, materials and water pass. Riparian areas characteristically have a high water table and are subject to periodic flooding and influence from the adjacent water body. These systems encompass wetlands, uplands, or some combinations of these two land forms. They will not in all cases have all the characteristics necessary for them to be classified as wetlands."

National Research Council: “Riparian areas - Transitional between terrestrial and aquatic ecosystems and are distinguished by gradients in biophysical conditions, ecological processes, and biota. They are areas through which surface and subsurface hydrology connect water bodies with their adjacent uplands. They include those portions of terrestrial ecosystems that significantly influence exchanges of energy and matter with aquatic ecosystems (i.e., a zone of influence).”

Some relevant publications for which abstracts or summaries were not found:

Atwill, E. R. 1998. Assessing the link between rangeland cattle and waterborne Cryptosporidium parvum infections in humans. Rangelands 18(2).

Beymer, R. J., and J. M. Klopatek. 1992. Effects of grazing on biological soil crusts in pinyon-juniper wood- lands in Grand Canyon National Park. American Midland Naturalist 127:139-148.

Bock, C. E., J. H. Bock, W. R. Kennedy, and V. M. Hawthorne. 1984. Responses of birds, rodents and vegetation to livestock exclosures in a semi-desert grassland site. Journal of Range Management 37:239–242.

Bock, C. E., and J. H. Bock. 1993. Cover of perennial grasses in southeastern Arizona in relation to livestock grazing. Conservation Biology 7:371–377.

Bock, C. E., L. Kennedy, J. H. Bock, and Z. F. Jones. 2007b. Effects of fire frequency and intensity on velvet mesquite in an Arizona grassland. Rangeland Ecology & Management 60:508–514.

Chan, David J. 2013. Using ecosystem services to understand the impact of land cover change: a case study of the upper San Pedro watershed. Master Thesis for University of Arizona School of Natural Resources and the Environment.

Chaney, E., W. Elmore, and W.S. Platts. 1990. Livestock grazing on western riparian areas. Northwest Resource Information Center, Inc. Eagle, Idaho.

Chaney, E., W. Elmore, and W.S. Platts. 1993. Managing Change: livestock grazing on western riparian areas. Northwest Resource Information Center, Inc. Eagle, Idaho.

Donahue, D. L. 1999. The Western Range Revisited: Removing livestock from public lands to conserve native biodiversity. University of Oklahoma Press, Norman OK.

Dosskey, Michael. 1996. Viewpoint; Applying riparian buffers to Great Plains rangelands. Journal of Range Management 51:426-431 July 1998. USDA Forest Service Rocky Mountain Research Station National Agroforestry Center, and the University of Nebraska School of Natural Resource Sciences, Lincoln. Neb. 68583-0814.

Flather, C. T., L. A. Joyce, and C. A. Bloomgarden. 1994. Species endangerment patterns in the United States. Pp. 42. USDA Forest Service, Ft Collins.

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Gifford, G. F., and R.H. Hawkins. 1976. Grazing systems and watershed management: A look at the record. Journal of Soil and Water Conservation 31:281-283.

Stevens, Lawrence, Jeri D. Ledbetter, Marguerite Hendrie. St. David Cienega Ecological Inventory and Assessment. Springs Stewardship Institute, Museum of Northern Arizona. Final Report December 20, 2012.