Exploring linkages between floodplains and riparian vegetation in small mountain watersheds

by Denine Michelle Schmitz

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Land Resources and Environmental Sciences
Montana State University

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Denine Michelle Schmitz

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INTRODUCTION

Riparian zones are linear areas adjacent to streams and, therefore, differ from other landscape features. While riparian zones occupy only 1-5% of the landscape area, (Hansen et al., 1995) the ecosystem functions attributed to riparian zones reach far beyond their boundaries. Riparian zones are considered 'integrators' of watersheds responding hydrologically, topographically, chemically and biologically to reach scale influences as well as to watershed scale ecological processes. Basin characteristics and regional climate drive watershed hydrology and generate variable stream flow characteristics—peak time, duration, rate of change, magnitude and frequency (Hornberger et al., 1998; Poff et al., 1997). Natural flow regimes drive spatial and temporal variability in biotic and abiotic components of riparian environments. The hydrologic environmental variability common to riparian zones yields a mosaic of vegetation patches that characterizes the riparian community (Baker, 1989; Bendix, 1994; Bendix & Hupp, 2000; Everett, 1968; Friedman et al., 1996; Gurnell & Gregory, 1995; Hupp & Osterkamp, 1996; Johnson, 1976; Piegay, 1997; Sigafoos, 1961). Riparian processes vary geographically in response to elevational, latitudinal and hydrological gradients (Patten, 1998). As these factors differ among basins, they create basin-specific hydrological environments (Hewlett, 1982; Hornberger et al., 1998). Consequently, the response of riparian vegetation to basin-specific hydrologic environments may produce riparian systems that, although related to broader geographic similarities, are representative of their individual basins.

Riparian ecosystems along single rivers have been the target of much attention due to potential loss or alteration resulting from human impacts such as development, flow regulation or changes in water quality or quantity (Johnson, 1976, 1994; Patten, 1998; Poff et al., 1997). Examples include, the Platte River in Nebraska (Johnson, 1994), the Animas in Colorado (Baker & Walford, 1995), the Provo River in Utah (Stromberg et al., 1999), the Snake River in Idaho (Merigliano, 1996), and the Missouri River in Montana (Scott et al., 1996). These studies focus on single large rivers or streams because replicating large watersheds is unrealistic. However, riparian studies of single streams or rivers can miss much of the regional variability in current and antecedent environmental conditions as well as associated vegetational responses. Regional studies of smaller watersheds do exist. Examples include investigations in the Great Basin of Nevada (Chambers et al., 1998; Miller et al., 2001) and the Upper Colorado River basin of Colorado (Baker, 1989, 1990). Studies of multiple smaller basins having common climate and geology capture potential variability in physical conditions and biotic responses of riparian zones. Regional studies offer a better understanding of within-region variability in riparian vegetational processes.

Information on riparian processes operating in large river systems may lose applicability when scaled to small streams. Physical and biological properties of fluvial and aquatic environments influence riparian environments through overland flows, channel migration, woody debris deposition and reworking of the channel and floodplain. Discharge, width, velocity and suspended sediment load generally increase while slope and bed sediment size tend to decrease with increasing basin size, distance downstream and basin position (Knighton, 1998; Thorne, 1997). Fluvial geomorphic processes change from a stream's headwaters to mouth. The upper third (smaller basin area) tends to be erosional, the lower third (larger basin area) depositional and the middle third a mix. Thus, the riparian zones in the upper third respond to predominantly erosional processes and those of the lower third to depositional processes. The mixture of aggrading and degrading processes drives yet another set of riparian responses along the middle reaches. While hillslope processes, glaciation, and tectonic activity add variation the longitudinal trend of erosional upper reaches to depositional lower reaches persists (Knighton, 1998). Thus, riparian ecosystems of large watersheds may have a different character than those of small watersheds due to associated scale-dependent processes.

Several examples of research in small watersheds (basin areas less than 500 km^2) illustrate both what is being learned and its limited extent. Geographically, small watershed riparian studies have been conducted in humid regions such as Virginia, USA (Hupp, 1983; Hupp & Osterkamp, 1985) and New Forest, England, (Gurnell & Gregory, 1995) as well as arid regions like Southern California, (Bendix, 1994, 1997, 1999) and the Great Basin, Nevada (Castelli et al., 2000; Chambers et al., 1999; Miller et al., 2001). The small watersheds in the semi-arid northern Rocky Mountains are relatively unexamined (Patten, 1998).

Basin level variables such as elevation, fire history, landscape cover types and valley width integrate with reach level variables such as elevation above the thalweg of a floodplain position, substrate type and stream gradient to form an array of riparian habitats (Baker, 1989; Bendix, 1994). Further, any change causing a shift in the distribution of basin or reach controls elicits change in the composition and structure of the vegetation mosaic (Bendix, 1994). Because the distribution of basin and reach level variables is dependent on basin size and position, riparian communities will likely reflect these changes.

The influence of hydrologic and sedimentologic conditions creates spatial and temporal diversity in riparian areas of both large and small watersheds. Temporally, seasonal and annual patterns in physical processes form a variety of patch histories across the floodplain (Baker, 1988; Bendix, 1994; Chambers et al., 1998; Sigafoos, 1961). Spatially, species composition and structure develop in relation to the effects of hydrological processes as they vary across the floodplain. For example, flood-tolerant species occur near the channel while those sensitive to the effects of flooding tend to grow higher on the floodplain (Gurnell & Gregory, 1995; Hupp, 1983; Hupp & Osterkamp, 1985, 1996). Woody debris creates safe sites for establishing vegetation and potentially stabilizes portions of the floodplain. Time and space work synergistically in that the influence of time-dependent variables has a spatial component (Bendix, 1994). For instance, the spatial structure of riparian woody vegetation is influenced by the spatial diversity of pre-flooding conditions, duration of inundation and time since the last major flood event (Chambers et al., 1998; Miller et al., 2001). Further, species composition and structure are functions of floodplain topography and substrate properties such as water table depth, soil texture and redox potential (Bendix, 1999; Castelli et al., 2000; Gregory & Gurnell, 1998; Stromberg et al., 1996). While these processes exist in small and large basins, their nature varies with basin size and position (i.e. erosional vs.

depositional). Thus, the spatial and temporal effects of physical processes on riparian vegetation operating in small watersheds will likely differ from those in large basins.

Autogenic, or internal, processes also alter the environment through shading, competition, facilitation, nitrogen fixation, etc. Allogenic, or external, changes such as early ground water level decline, burial by coarse or fine sediment, herbivory, litter accumulation, woody debris deposition, etc. can cause varying plant responses and alter successional trajectories. Depending on the phenological phase of a plant, these changes can cross environmental thresholds causing different plant responses (Chambers, 2000; Chambers et al., 1998). By increasing root mass, hindering shoot growth, inducing self-thinning or dying (these are just a few of the possible responses) the responses of plants across the floodplain create an array of patch communities, all of which are on successional trajectories specific to the history of ecological conditions for a locale. Thus, patch diversity is variable in a given zone.

Ranging from predominantly allogenic to predominantly autogenic, the mechanisms shaping riparian vegetation within and among basins are diverse (Amoros et al., 1987). As floods of different magnitudes and frequencies physically alter the floodplain environment within biological limits, associated plant communities respond accordingly. Below biological thresholds, allogenic influences elicit little vegetation response. This allows autogenic influences to predominate in such forms as competition, nitrogen fixation, and litter formation (Malanson, 1993). Thus, sensitivity of riparian plant composition and structure reflects the influence of allogenic factors associated with fluvial dynamics.

The research described above documents how vegetation dynamics, watershed hydrology and floodplain environment influence riparian vegetation. However, the degree to which these linkages affect riparian composition and structure is not well explored, especially for the herbaceous stratum. Herbaceous species compose the majority of species in riparian zones of the intermountain west. These species are more indicative of water table levels than woody species (Stromberg et al., 1996). Herbaceous roots tend to be fibrous and lend more stability to riparian soils than woody species (Dunaway et al., 1994; Kleinfelder et al., 1992). Because the herbaceous layer represents an important component of the vertical structure of the riparian community, further research is needed on its response to hydrogeomorphic processes and landforms.

The goals of this research are designed to address the role of herbaceous plants in the riparian communities in the Northern Rocky Mountains by examining floodplain dynamics of intraregional small mountain basins. Components of the small mountain riparian systems explored in this study are:

1) differences in hydrogeomorphic environments
2) basin-specific characteristics in riparian plant community composition and structure, emphasizing understory vegetation
3) differences in the set of biotic and abiotic (see Table 3 in Methods) variables that best predict herbaceous understory composition at target recurrence intervals

This thesis addresses the goals above with three objectives. Using three basins in the Upper Yellowstone River watershed this project will:

1) describe the hydrogeomorphic environments and the corresponding riparian vegetation composition and structure, with detailed characterization of the herbaceous community. This description will serve as a baseline for understanding ecological responses to future land use changes in subwatersheds of this basin.
2) compare the between-basin relationships of biotic and abiotic factors that contribute to riparian plant community composition and structure.
3) document and predict changes across the floodplain in the herbaceous understory based upon other vegetation and hydrogeomorphic parameters.

Study Area

The study included private and public lands in the Upper Yellowstone River watershed (Figure 1). The Northern Range of Yellowstone National Park (YNP) marked the southern limits of the study area. Outside YNP, the northern boundary lay at the mouth of Yankee Jim Canyon where Tom Miner Basin confluences with the Yellowstone River and included Tom Miner and Cinnabar basins (Figure 1). Watersheds studied within YNP were Soda Butte, Pebble and Cache Creek basins (Figure 2). Outside the park, Tom Miner and Cinnabar Creeks were considered one watershed and will be referred to as Tom Miner Basin hereafter. Soda Butte and Pebble Creeks were treated similarly and will be referred to as Soda Butte Creek hereafter. Cache Creek will simply be referred to as Cache Creek.

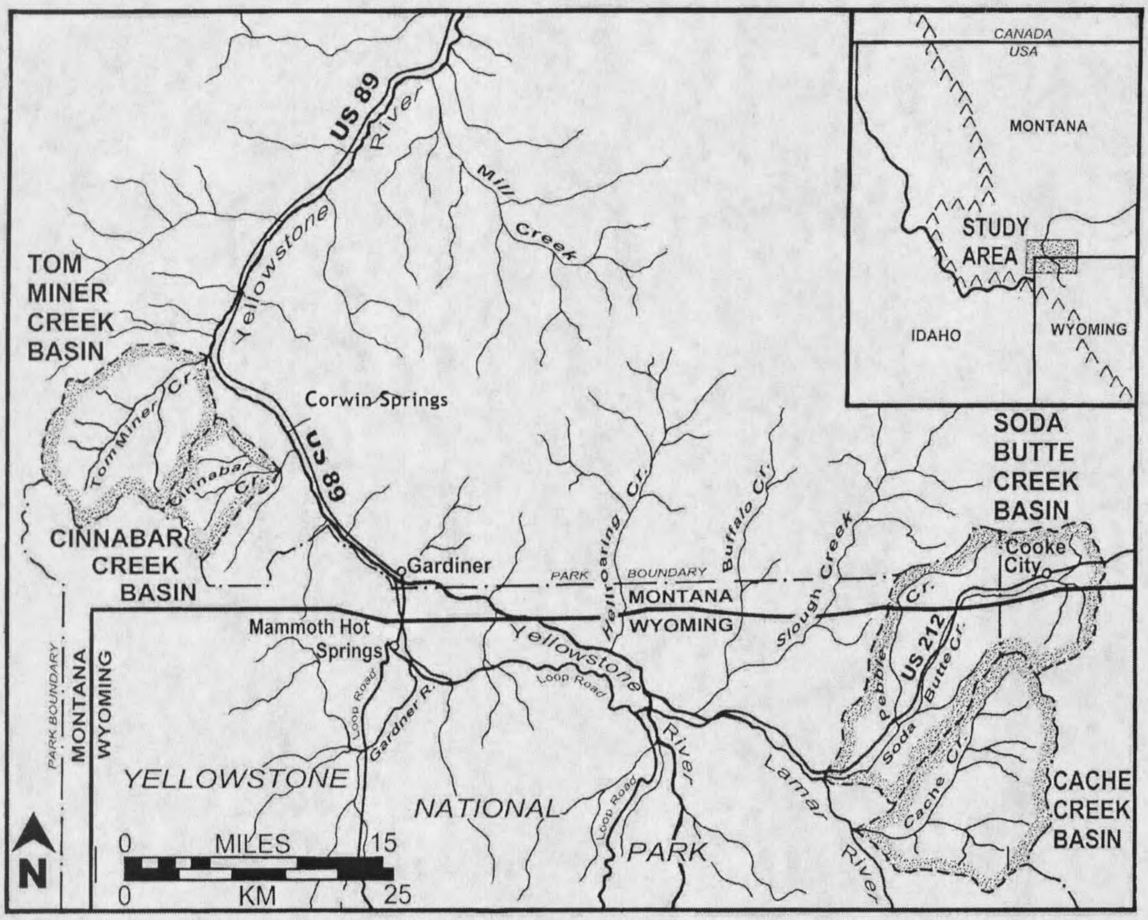

Figure 1. Map of study area modified from Legleiter et al. (in press) courtesy of Karen Wynn Fonstad.

Geologic environments are similar among the three basins. All three basins are glaciated valleys with over-steepened valley sides and shallow surficial deposits and soils making them prone to flash flooding during summer convective storms (Meyer, 2001). The dominant bedrock geology of Tom Miner Basin includes Archean metamorphic, Eocene volcanics and Paleozoic sedimentary (Vandeberg, 1993). Soda Butte and Cache Creeks bedrock geology encompasses Tertiary Volcanics and Paleozoic sedimentary rocks (Meyer, 2001; Prostka et al., 1975). Basin floor surficial geology in all three basins is dominated by glacial alluvium and local flood and debris flow alluvium. Tom Miner Basin also shows evidence of postglacial tectonism (Vandeberg, 1993).

All basins have similar land cover types including alpine plant communities, coniferous forests, deciduous groves, mesic meadows, shrublands and riparian areas (Marston & Anderson, 1991). Coniferous forests consisted of *Picea engelmannii*, *Pinus contorta*, *Pseudotsuga mensizii*, and *Abies lasiocarpa*. *Populus tremuloides* dominate the deciduous groves. Shrublands were found on low elevation, south facing slopes and included *Rosa woodsii*, *Rubus* spp., *Lonicera* spp., *Symphoricarpos* spp., *Artemisia* spp., *Vaccinium* spp., and *Ribes* spp. Riparian plant associations ranged from Coniferous spp./*Salix* spp. in the upper reaches to *Populus trichocarpa*/*Salix* spp. in the lower portions of the basins. The climate is semi-arid with cold winters, mild summers and 75-85% of the moisture comes as snow or rain on snow (Despain, 1987). Average winter daily high temperatures range from -15°C to -4°C while those of summer vary from 3°C to 23°C (Vandeberg, 1993). Precipitation falls all year long with two peaks – one in winter and one in early summer. Mean annual precipitation of the valley floors is ~30-45 cm (Meyer, 2001). The majority of runoff occurs from snowmelt in late spring (Figure 3). Pacific maritime weather mixes with Great Plains weather over mountain-valley topography to create precipitation distribution that varies with elevation (Despain, 1987; Hansen et al., 1995). In 1996 and 1997, large magnitude floods occurred in the Upper Yellowstone River watershed, each estimated at 100-yr return intervals (Figure 1). These floods caused much channel reworking. While these were wide spread disturbance events, some tributaries were affected more than others.