THE ROCKY MOUNTAIN WEST:
A COMPENDIUM OF GEOGRAPHIC PERSPECTIVES

Edited by MICHAEL J. KEABLES

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THE ROCKY MOUNTAIN WEST

A COMPENDIUM OF GEOGRAPHIC PERSPECTIVES

Michael J. Keables

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Editor-in-Chief

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Michael J. Keables

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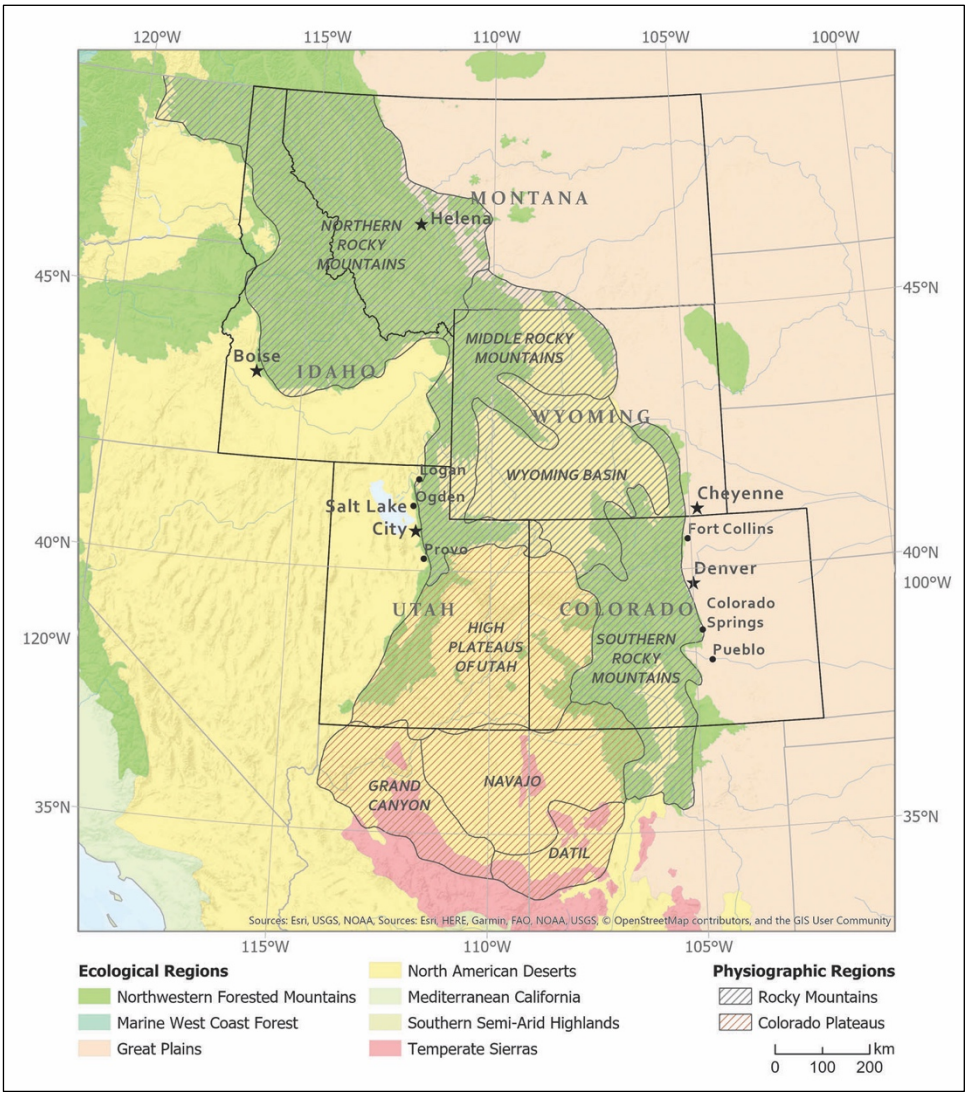

Figure 1. Political, physiographic and ecological regions of the Rocky Mountain West. Sources: Physiography (Fenneman and Johnson 1946), Level I ecoregions (Omernik 1987).

The concept of region is fundamental to geography, and as one can imagine, there are several approaches to defining the Rocky Mountain West (Figure 1). For many, the region is simply viewed as five political units, namely the states of Colorado, Idaho, Montana, Utah and Wyoming. Traditionally, the Rocky Mountain West is defined by the physiography of the landscape, comprised of the Northern,

Middle, and Southern Rocky Mountains, the Wyoming Basin, and the High Plains of Utah province of the Colorado Plateaus (Fenneman and Johnson 1946). Two ecoregions (areas of similar ecosystems)—the Northwestern Forested Mountains and the North American Deserts—in large measure the result of climate and physiography, produce similar spatial patterns. (Omernik 1987; Omernik and Griffith 2014).

Regardless of how the region is defined, the Rocky Mountain West is a year-round haven for outdoor enthusiasts. Skiers flock to resorts, expansive and modest alike, in search of the famous "champagne powder." Hikers and backpackers relish opportunities to explore vast areas of uninhabited terrain and wilderness. Four of the top-ten-visited national parks are located in the Rocky Mountain West, with attendance exceeding 15 million visitors in 2019: Rocky Mountain National Park (4.7 million), Yellowstone National Park (4 million), Grand Teton National Park (3.4 million) and Glacier National Park (3 million) (NPS 2020). In addition to the nearly two million hectares of national park land (White 2016), over 40 million hectares of national forests and grasslands offer public access to fishing, hiking, camping, hunting, and other forms of outdoor recreation (USFS 2017).

The economy of the region is highly diversified. Resource extraction (primarily mining and forestry) and agriculture are prominent in rural communities; technology, finance, government, manufacturing, education, and scientific research and engineering are key industries in the urban centers. Tourism is a major contributor throughout. The Front Range Urban Corridor—Cheyenne, Fort Collins, Boulder, the Denver metropolitan area, Colorado Springs, and Pueblo—and the Wasatch Front Urban Corridor—Logan, Ogden, the Salt Lake City metropolitan area, and Provo—are the economic engines for much of the region (Figure 1), contributing to more than 60% of the combined GDP of the five Rocky Mountain states (BEA 2019).

The scenic environment, the Western lifestyle, and a strong economy are attractive to many, and as a result, the population of the region is growing. Since 2010, the populations of Colorado, Idaho and Utah are each estimated to have increased by 15%, with the majority of growth occurring in the urban centers (U.S. Census Bureau 2019). Ten cities along the Colorado Front Range were recently ranked in the top 50 fastest-growing cities in the country (McCann 2019). This rapid growth has exerted pressures on urban and rural infrastructures alike. Increased traffic congestion, be it getting across town, driving between Front Range cities, or heading up to the ski resorts for a day on the slopes—where a normal 90-minute drive quickly devolves on the weekends into a three-hour slog—challenges the patience of commuters. The growing population in the urban corridor taxes the availability of affordable housing, driving the price of single-family homes beyond what many can afford. In ski resort towns, access to housing has become so acute that some resorts offer subsidized housing or housing allowances to ensure employees have a place to live. Popular mountain hiking trails now require reservations, and backcountry camping permits are becoming increasingly available only by lottery.

While these are just a few examples of how the intersection of nature and people is shaping this fascinating region, the contributors to this volume offer a broad range of geographic insights about the Rocky Mountain West. Included are topics directly impacting the region, as well as the region's influence on its neighbors. Divided into five sections, the authors address the physical environment and cultural landscapes unique to the Rocky Mountain West, the interaction between people and the environment, the impact of development on land-use change, and perspectives on the urban geographies of Denver. The chapters provide an introduction to the history of the region, from prehistoric settlement, through the westward expansion of the U.S., to the evolution of Denver—from a rough-and-tumble supply town for gold and silver miners to a cosmopolitan city. Additional chapters address timely issues of conservation practices related to water supply and recreation, the impact of population growth on the environment and resultant changes in land use, and examples of ties between people, places and nature. Collectively, this work provides a geographic lens through which to view the connections of the region's physical and cultural environments, and the complex relationships that result.

Acknowledgements

The idea to publish a digital book of companion essays for the 2020 AAG Annual Meeting in Denver originated with AAG President Dave Kaplan at a Local Arrangements Committee meeting in August 2019. Since that meeting, working under an abbreviated production timeline (seven months from conception to publication), numerous individuals

collaborated on the publication of the book. The Editorial Advisory Board, comprised of local geographers from several institutions, solicited contributions, reviewed abstracts, and provided guidance with respect to the book's compilation and organization. Authors submitted manuscripts, and external reviewers provided their recommendations, all within a matter of weeks. Patricia Guerra, my administrative assistant, assumed double-duty as editorial assistant, and Rebecca Pendergast of the AAG designed the cover artwork and provided guidance on publication specifications. Without these collective efforts, this book would not have been possible. To everyone involved with this project, I extend my heartfelt gratitude.

References

[BEA] Bureau of Economic Analysis. 2019. Annual Gross Domestic Product. U.S. Department of Commerce. Accessed February 29, 2020. https://www.bea.gov.

Fenneman, N. M. and D. W. Johnson. 1946. *Physiographic divisions of the conterminous U.S.* Reston, VA: U.S. Geological Survey.

McCann, A. 2019. Fastest-growing cities in America. Accessed March 1, 2020. https://wallethub.com/edu/fastest-growing-cities/7010/.

[NPS] U.S. National Park Service. 2020. Visitation num-bers. U.S. Department of the Interior. Accessed February 29, 2020. https://nps.gov/aboutus/visitation-numbers.htm.

Omernik, J. M. 1987. Ecoregions of the conterminous United States. Map (scale 1:7,500,000). *Annals of the Association of American Geographers* 77 (1):118-125.

Omernik, J. M. and G. E. Griffith. 2014. Ecoregions of the conterminous United States: Evolution of a hierarchical spatial framework. *Environmental Management* 54:1249–1266. doi:10.1007/s00267-014-0364-1.

U.S. Census Bureau. 2019. Annual population estimates, estimated components of resident population change, and rates of the components of resident population change for the United States and Puerto Rico: April 1, 2010 to July 1, 2019. Accessed March 1, 2020. https://www.census.gov/data/datasets/time-series/demo/popest/2010s-state-total.html.

[USFS] U.S. Forest Service. 2017. Forest inventory and analysis. FS-1075, U.S. Department of Agriculture, Washington, DC.

White, M. 2016. *Guide to the National Parks of the United States.* 5th ed. Washington, DC: National Geographic Society.

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FOREWORD

When I began attending American Association of Geographers national meetings 36 years ago, one of the most anticipated items was the annual edited book that came in our registration packet. This would be a special volume dedicated to the city and region where the meeting was held. Within it were chapters detailing all kinds of fascinating aspects of the region, written by geographers with expertise and wisdom. I still have a large collection of these regional geographies on my bookshelf. Once those collections were no longer published in the early 2000s, the AAG lost a great store of regional knowledge.

So I am delighted to announce that the Association has published a new edited book entitled *The Rocky Mountain West: A Compendium of Geographic Perspectives*. This book is edited by Michael Keables and includes an editorial board of local experts. They sought essays by issuing a call for papers to all members of the AAG, harnessing the contextual knowledge that only geographers can provide.

Mike and his board were able to obtain some 38 chapter proposals. After a process of submission and peer review, they selected 25 finished chapters from geographers representing many different kinds of institutions. These are organized into five themes: physical geography, cultural geography, human-environment interaction, land-use change, and essays on the city of Denver.

This is a fully produced, peer-reviewed book, available as a pdf to every conference attendee and as a printed publication to those who can pay a nominal fee. Speaking for myself, I will be eager to add it to my older collection of regional books from past AAG meetings.

The American West is filled with dramatic landscapes, ecological challenges, a fascinating and tortured historical legacy, an rapid demographic and cultural changes. Our 2020 meeting in Denver would have provided us with a front door seat to these features. Unfortunately it had to be cancelled for public health concerns but we look forward to meeting there again in the near future. This new regional compendium provides insights into all of these issues and more. I hope that this inspires the development of new regional books on the Pacific Northwest, the New York region, and for all AAG meeting sites to come.

David H. Kaplan
AAG President 2019-20

THE PHYSICAL ENVIRONMENT OF THE ROCKY MOUNTAIN WEST

Grand Teton National Park, Wyoming. Photo by Sharon Kehl Califano.

COLORADO'S TERRAIN-TIED METEOROLOGY

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Introduction

Terrain rules the climate of the Rocky Mountain West. A quick glance at temperature (Figure 1), precipitation (Figure 2), and elevation (Figure 3) maps of the contiguous U.S. corroborates this claim: The tangled patterns in temperature and precipitation across the western half of the contiguous U.S. closely align with the underlying terrain. In the eastern half, temperature and precipitation maps show gradual, more orderly transitions. Specifically, temperature (Figure 1) is closely connected to latitude, while precipitation (Figure 2) reveals the strong influence of the Gulf of Mexico.

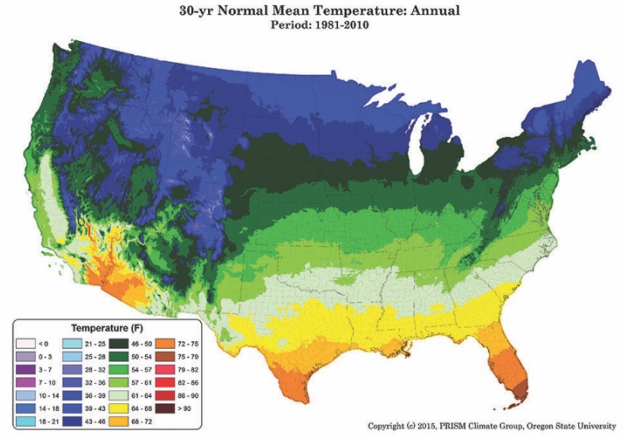

Figure 1. U.S. annual mean temperature, 1981-2010. Parallel west-east isotherms between the Rockies and the Appalachians indicate the control of latitude on temperature (Copyright 2020, PRISM Climate Group).

Any mountainous region could serve as a platform to explore terrain ties to meteorology. However, within the Rocky Mountain West, Colorado's landscape/atmosphere interactions are remarkable. The state's geography captures the meteorological phenomenon of the Rocky Mountains and the Great Plains, and the lively processes operating near the intersection of the two physiographic regions. The sharp topographic relief in the mountainous western sections, and to a lesser extent, the eastern sections (Figure 6), clearly maps elevation's inverse relationship with temperature (Figure 4) and direct relationship with precipitation (Figure 5).

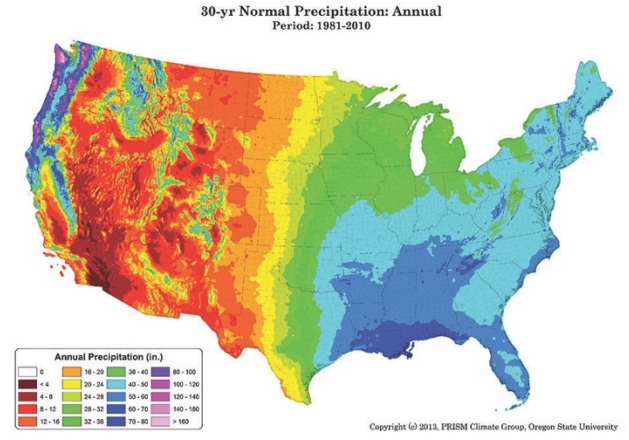

Figure 2. U.S. annual mean precipitation, 1981-2010. Tight north-south isohyet gradient from North Dakota to West Texas marks approximate boundary between rain shadow cast by Rockies and the reach of Gulf of Mexico moisture (Copyright 2020, PRISM Climate Group).

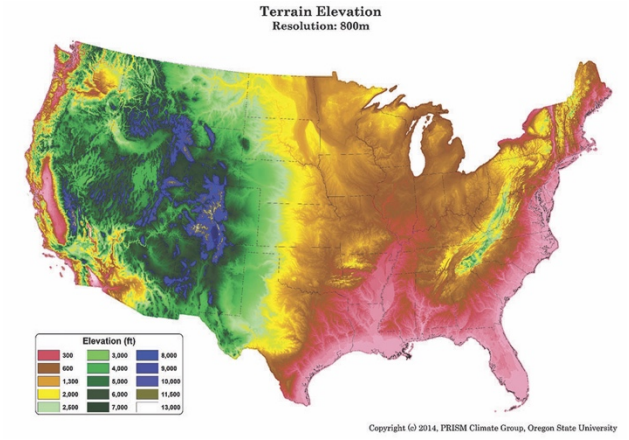

Figure 3. U.S. elevation. Note similarity in overall pattern of the direct relationship with Figure 2, U.S. annual mean precipitation (Copyright 2020, PRISM Climate Group).

First, this paper portrays the topography of Colorado and illustrates the state's vibrant climatology. Next, a collection of meteorological processes —the Colorado low, mesoscale convective complexes (MCCs), atmospheric rivers (ARs), upslope

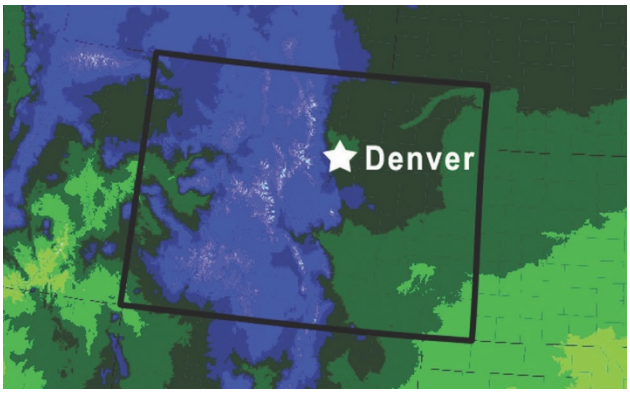

Figure 4. Temperature. Colorado annual mean temperature. Generally, the blues (cooler temperatures) cover the higher elevations. 1981-2010. Legend values same as Figure 1 (Copyright 2020, PRISM Climate Group).

precipitation, downslope winds, the Denver Cyclone, and valley inversions/cold air drainage—are reviewed and tied to Colorado's terrain features. The two goals of this paper are for readers to i) learn about specific couplings between the Colorado landscape and meteorological processes and ii) to absorb what it is like to live in a region where a parka, a rain jacket, a short sleeve shirt, a sturdy building, and a helmet might be essential for comfort or survival *all in one day*.

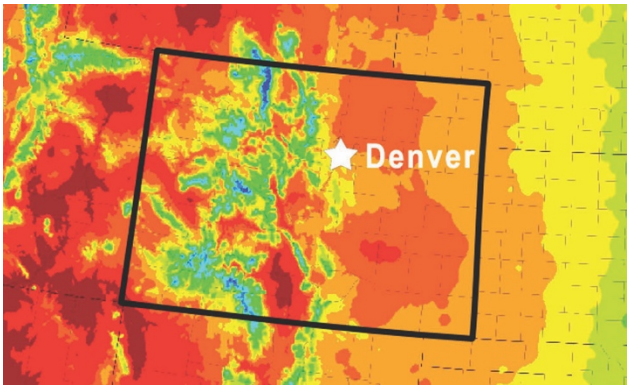

Figure 5. Precipitation. Colorado annual mean precipitation. Generally, the greens (higher precipitation) cover the higher elevations. 1981-2010. Legend values same as Figure 2 (Copyright 2020, PRISM Climate Group).

Landscape

Colorado's average elevation of 2,073 m (6,800 ft) means that Coloradans endure the highest state in the Union. While Alaska and California possess higher high points, Colorado claims more mountain summits above 4,267 m (14,000 ft) (called

Figure 6. Elevation. Legend values same as Figure 3 (Copyright 2020, PRISM Climate Group).

"Fourteeners" in Colorado) than any other state. About 75% of the United States' land above 3,048 m (10,000 ft) covers Colorado. This equates to 28,937 km^2 (11,172 mi^2), or 11% of Colorado. The state's highest summit, Mount Elbert, reaches 4,399 m (14,433 ft). Denver, Colorado's "Mile High City," sits 463 m (1,520 ft) *below* the average elevation of the state.

A dozen or so major mountain ranges and high plateaus shape the western 60% of Colorado (Figure 7). The largest of these ranges, the San Juan Mountains, covers 12% of the state. Other prominent ranges include the Sawatch, the Sangre de Cristos, and the Front Range. Pikes Peak, an isolated mountain massif near Colorado Springs, juts eastward into the Great Plains where its eastern slope descends 2,438 m (8,000 ft) in only 11 km (7 mi) (Figure 7).

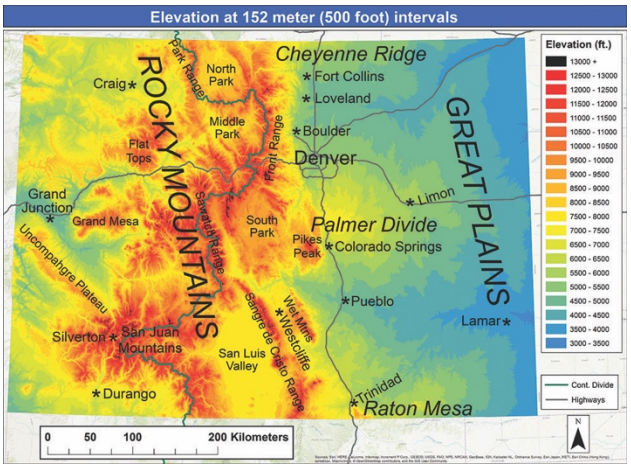

Figure 7. Elevation map of Colorado with place names.

High plateaus run from the southwestern part of Colorado off towards the northeast. These include the Uncompahgre Plateau, Grand Mesa, and Flat Tops (Figure 7). Four expansive, high, intermountain basins called 'parks' in Colorado provide open views of distant mountain ranges. From north to south, these are North Park, Middle Park, South Park, and the San Luis Valley. The latter covers 7,770 km^2 (3,000 mi^2), sits at 2,345 m (7,700 ft), and contains North America's tallest sand dunes.

The Continental Divide snakes longitudinally through the central part of the state, passing a mere 63 km (39 mi) west of the Colorado State Capitol Building in Denver (Figure 7). Headwaters of the Rio Grande, Arkansas, Platte, and Colorado, spill from both sides of the Divide, cutting deep canyons along the way. To the west of the Divide lies the Western Slope, i.e., the rugged landscape sloping down to the Utah border. Three eastward-stretching ridges intrude into Colorado's Great Plains: Palmer Divide, Cheyenne Ridge, and Raton Mesa (Figure 7).

Roughly 85% of Colorado's population inhabits the corridor running along the Rocky Mountains/ Great Plains interface (Figure 7). This stretch includes the Front Range-proximate cities of Fort Collins, Loveland, Boulder, and Denver, and to the south of the Palmer Divide, Colorado Springs, Pueblo, and Trinidad. East of this corridor lies the 40% of the state that is sloped but relatively flat. The lowest elevation in Colorado, at 1,010 m (3,315 ft), sits in the thalweg of the Arikaree River where it crosses into Kansas just south of the Nebraska border.

Climate

Colorado's physical geography favors low humidity, high evaporation, and drastic diurnal and seasonal temperature fluxes. With its 3,353 m (11,000 ft) of relief, Colorado supports windswept tundra (generally found north of the Arctic Circle) to cold desert to hot-summer Mediterranean climates. Colorado is an interior state that sits in the cumulative rain shadow cast by California, Nevada, Utah, and other western states' moisture-wicking mountains (Figure 5).

The average annual precipitation across the state is 43 cm (17 in) but, because this is Colorado (Figure 5), the values range from 18 cm (7 in) in the San Luis Valley to more than 1.5 m (60 in) in the Park Range in northwest Colorado (Figure 7) (Doesken, Pielke, and Bliss 2003). Annual snowfall totals vary from 64 cm (25 in) (NCDC 2004) in the lower elevations of west central and southeast Colorado to over 10 m (400 in) in the Park Range (Figure 7) (Doesken, Pielke, and Bliss 2003).

Despite the generally dry climate of Colorado, moisture from the Pacific Ocean and Gulf of Mexico occasionally soak Colorado. For example, the Park Range (Figure 7) receives the most overall precipitation in the state because moist air from the Pacific navigates there through a narrow gap between Utah's Wasatch Range and Wyoming's Teton/Wind River/ Absorka complex (Parker 2002). Other pathways of moisture entering Colorado, though welcomed, can leave flood damage in their wake.

Broad Scale Terrain Ties

Friction generated by underlying mountainous terrain weakens and slows weather disturbances moving into Colorado from the west (Achtor and Horn 1986). In the Northern Hemisphere, slowing the westerlies deflects the wind direction from geostrophic (parallel to isobars) to a path that is more aligned with the high-to-low pressure gradient. This geostrophic adjustment deflects wind toward the north thus initiating the counterclockwise spin that helps create centers of circulation, or cyclogenesis—the birth of a low pressure. Furthermore, when air descends the leeward side of a mountain range, as it does over the Sangre de Cristo Range and Wet Mountains (Figure 7), the column of air is vertically stretched, which tightens the spin radius and increases wind speed. The highest concentration of cyclogenesis in North America—about 16 per month—occurs along the eastern slopes of the Rocky Mountains in southeast Colorado (Whittaker and Horn 1981).

Once formed, these "Colorado lows" rapidly advect warm moist air from the Gulf of Mexico and cool air from the north and trek energetically off towards the Great Lakes Region. Colorado lows can impact Louisiana, southern Manitoba, and New England (Zielinski and Keim 2003, 64). Depending on the season, strength, and track, these cyclones can produce freezing rain, severe thunderstorms, flooding, high winds, and blizzards (Petterssen 1956, McGinley 1982, Clark 1990, Schultz and Doswell 2000).

One Colorado low, the March 13 and 14, 2019 "bomb" cyclone, intensified so rapidly over southeast Colorado (Figure 8) that it broke a state record and a city record: lowest pressure in Colorado (970.4 mb (28.7 in) near Lamar) and highest wind gust at the

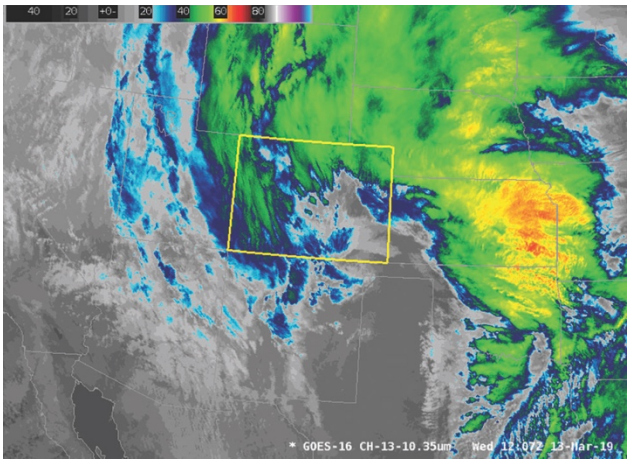

Figure 8. IR satellite image of the "bomb" cyclone, 6:00 am local time, 13 March 2019. Colorado outlined in yellow (NWS 2019a).

Colorado Springs airport (155 kmph (96 mph)) (NWS 2019a). To qualify as a "bomb" cyclone, the pressure must drop at least 24 mb (0.71 in) over 24 hours (NOAA 2020). The storm spawned tornadoes in New Mexico, Texas, and Kentucky, blew 26 rail cars off a trestle in New Mexico, stranded over 1,500 motorists in the Colorado Springs region alone (Figure 9), and caused historic flooding in Iowa, Nebraska, and South Dakota (NWS 2019a). Blizzard conditions lasted nine consecutive hours in Denver and 11 in Colorado Springs. The day after the storm, 46,000 Denver residents remained without power (Barnett 2019).

Figure 9. Abandoned cars in Colorado Springs, Colorado, 14 March 2019 (NWS 2019a).

Mountain ranges in the mid-latitudes, such as those in Colorado, are favored locations for thunderstorm development (Banta and Schaaf 1987, Vogt and Hodanish 2014). Driven by thermally forced upslope flow from differentially and rapidly heated complex topography (Tripoli 1986, Schaaf, Wurman, and Banta 1988), mountain-born storms generally form in the late morning to early afternoon (Schaaf, Wurman, and Banta 1988, Tucker and Crook 2005). In Colorado, storms eventually move east into the plains where, if the environment is favorable, strengthen, or their cool outflow initiates new thunderstorms (Wilson et al. 1988). These eastward-moving thunderstorms often coalesce into vast organized clusters called Mesoscale Convective Complexes (MCCs) (Maddox et al. 1986). About 25% of the MCCs in the U.S. originate high in the Rocky Mountains (Maddox et al. 1986) and up to 18% of the total warm season precipitation that falls in the Central U.S. is traceable to MCCs (Ashley et al. 2003). More than 60% of the warm season precipitation over the Central U.S. is nocturnal, falling between 10:00 p.m. and 8:00 a.m. local time (Wetzel, Cotton and McAnelly 1983), and traceable to MCCs that formed earlier in the day or the day before off to the west.

Forced by strong orographic convergence and uplift, Colorado periodically catches concentrated bands of moisture from the Pacific Ocean that arrive in the form of atmospheric rivers (ARs) (Rutz, Steenburgh and Ralph 2014, Alexander et al. 2015, Ralph et al. 2019, Yochum, Scott and Levinson 2019). In 2017, five ARs impacted Colorado in just two winter months, significantly and rapidly bolstering the snowpack (CSAS 2017). During the first two weeks of March 2019, five ARs impacted Colorado (CW3E 2019). This moisture led to heavy snow and resulted in 1,000 avalanches reports submitted to the Colorado Avalanche Information Center (CAIC) (NWS 2019b). One March 2019 avalanche covered U.S. Highway 550 in southwest Colorado with 18 m (60 ft) of snow (Figure 10) causing a 19-day road closure. Another briefly shut down Interstate 70 with 1.8 m (six ft) of snow (NWS 2019a).

The Colorado mountains intercept Pacific Ocean and Gulf of California moisture via the North American Monsoon (NAM) (Hales 1974). The NAM transports low-level subtropical moisture northward in response to a seasonal change in wind direction (Tang and Reiter 1984). Specifically, from July through September (Hales 1974), moisture from the eastern tropical Pacific Ocean, Gulf of California, and to a lesser extent, the Gulf of Mexico, is transported northward via a series of teleconnected mechanisms that includes a thermal low, midlatitude troughs, and tropical easterly waves (Adams and Comrie 1997). The NAM impacts all of Colorado (Adams and

Figure 10. View inside U.S. Highway 550 snowshed filled with snow carried in from an avalanche on opposite side of the valley that pushed up onto the other side (highway side) of the valley. Showshed is 18 km (11 mi) north of Silverton (Figure 7) (AIC/CDOT).

Comrie 1997, Higgins et al. 1997) by providing all but the northwest quarter of the state with more than 30% of its July, August, and September moisture (Douglas et al. 1993). In Colorado, NAM-generated thunderstorms are most impactful along the southern flanks of the San Juan Mountains (Vogt and Hodanish 2016) (Figure 7). In 1999, a NAM thunderstorm left a tributary of the Uncompahgre River in southwest Colorado 51 times its normal width (Avery et al. 2002). The 7.9 cm (3.1 in) of rain that fell on 30 July created a 100-year flood event. The same NAM moisture surge triggered 480 debris flows in the central part of the state (Godt and Coe 2007). For the Colorado Plateau, in which southwest Colorado is included, 50 to 90% of large flash floods occur during the NAM season—these events are the dominant agent of geomorphic change in this region (Hereford and Webb 1992).

Fine Scale Terrain Ties

This section focusses on atmospheric interactions with finer scale terrain features—ridges, mountains, and basins. An easterly upslope wind blowing across the Great Plains of eastern Colorado is subtly forced up, cooled, and, with the right conditions, saturates, condenses, and precipitates. With an opposite scenario, a westerly downslope wind, the air warms and dries. Because of the state's complex topography, a wind shift of only a few degrees (Figure 11) can boom or bust a precipitation or temperature forecast. This presents unique challenges to weather forecasters in the region. A quintessential terrain-driven winter storm on Colorado's Great Plains occurred in November of 2015 when a low pressure over south-

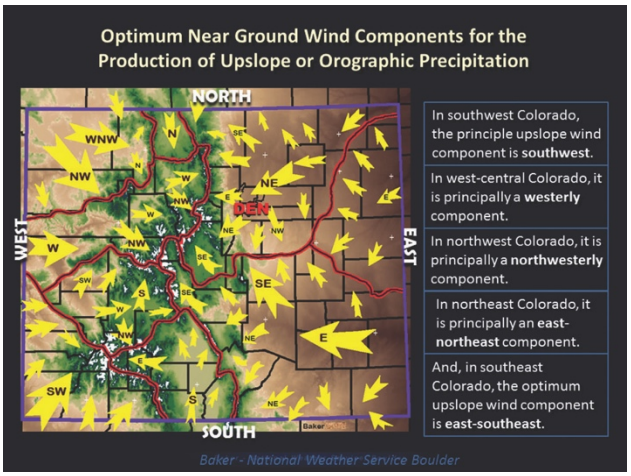

Figure 11. Yellow arrows indicate optimum near-ground wind components to produce upslope/orographic precipitation. Red lines show relatively higher elevation watershed boundaries. A slight shift in wind direction can change precipitation intensity/precipitation type/cloud cover/temperature and offers many forecasting challenges (NWS Boulder 2019).

western Kansas brought upslope winds (and snow) to the northern flanks of the Cheyenne Ridge, Palmer Divide and Raton Mesa, leaving all three ridges' southern flanks rather snow-free (Figure 12) (NOHRSC 2020).

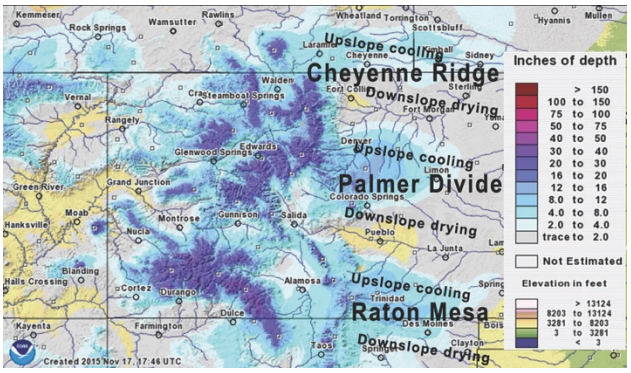

Figure 12. Modeled snow depth for 17 November 2015 from 15 November snowfall. Notice the terrain controls of the east-west running Cheyenne Ridge, Palmer Divide, and Raton Mesa, where northerly winds kept the south-facing slopes mostly snow-free. Modified from NOHRSC 2020.

One notorious multiday upslope orographically-enhanced storm that was intensified by moisture from the Pacific Ocean and the Gulf of Mexico (Najibi et al. 2019) impacted Colorado September 2013. In Boulder County, 45 cm (17.7 in) of rain fell (Figure 13), and the statewide 24-hour rainfall record of 30 cm (11.85 in) was established near Colorado Springs

(Gochis et al. 2015). The Front Range foothills-focused event resulted in several days of air evacuations and 18 counties placed into federal disaster area status (Gochis et al. 2015). The catastrophe is remembered as a 1,000-year rainfall event and a 100-year flood (Aguilar and Brennan 2013).

Figure 13. Bridge collapse causes three vehicles to fall into creek, 13 September 2013, Boulder County, Colorado (Aguilar and Brennan 2013).

Leeward sides of north-south oriented mountain ranges experience strong downsloping winds when air is forced over mountains and through narrow gaps in the mountains. Conditions are most favorable for strong, damaging winds at night (Whiteman and Whiteman 1974) and during the winter months (Julian and Julian 1969). Under these conditions, an inversion (e.g., when the atmosphere gets warmer—not cooler—with increasing height) is more likely to form: An inversion in place on the windward side of a mountain range, with the inversion's cap (lowest elevation of the warm air layer) near mountain top heights, forces and squeezes the cross-mountain flow just below the inversion height. After crossing over the mountain top, this compressed air rapidly accelerates down the leeward side, impacting the mountain base where the most severe winds occur. Strong leeside winds in the Rocky Mountains are known as Chinooks. In Colorado, Chinooks are generally more common in the Boulder and Westcliffe areas (NWS 2019c) where mountains to the west funnel westerly winds. Notorious Chinook events—all in Boulder and all in January—brought 193 kmph (120 mph) (Lilly and Zipser 1972), 209 kmph (137 mph) (Durran 2003), and 237 kmph (147 mph) (ESRL 2020) gusts. Another Chinook flattened 81 km^2 (20,000 acres) of old-growth trees on the western side of the Park Range (Figure 7) in northern Colorado October of 1997. This atypical easterly Chinook gusted to 180 kmph (112 mph) (Meyers et al. 2003).

Downslope winds can rapidly raise temperatures and melt snow—especially when a shallow cold airmass is displaced by a downsloping wind. On 8 January 2015 at the Colorado Springs airport, the temperature rose from -10C (14F) to 11C (52F) in only two hours (NCEI 2020) as winds increased from calm to westerly with gusts to 55 kmph (34 mph). The warming winds rapidly scoured away a thin layer of arctic air.

The Denver Cyclone, also known as the Denver Convergence Vorticity Zone (DCVZ), is an area of low pressure that forms over the Denver metropolitan region, roughly between the Palmer Divide and the Cheyenne Ridge (Szoke et al. 1984) (Figure 7). The circulation feature, which can form an eye much like a hurricane (Szoke 1991), generates severe weather, including tornado outbreaks (Szoke et al. 1984, Szoke and Augustine 1990). The development of the DCVZ is tied to southeasterly flow across the Palmer Divide that interacts with northerly flow east of the foothills that lie to the west of Denver (Crook, Clark, and Moncrieff 1990, Szoke 1991). The DCVZ forms more than one-third of the days June through August (Szoke and Augustine, 1990), and was in place for major Denver tornado outbreaks that occurred 3 June 1981 (Szoke et al. 1984) and 15 June 1988 (Szoke and Rotunno 1993).

A final example of a meteorological process tightly controlled by topography is wintertime cold air drainage and the resulting valley inversion. In Colorado's vast parks (Figure 7) and hundreds of smaller mountain-bound valleys, cold air that drains from surrounding higher elevations pools in low places. At night, with calm winds, clear skies, and a fresh snow cover, temperatures in river valleys, floodplains, and over frozen reservoirs plummet—from the collection of dense cold air and from surface radiational cooling. Alamosa, which sits in the mountain-bound San Luis Valley (Figure 7), is the coldest place in Colorado with an average annual temperature of 5.3C (41.6F) (NWS, 2020). The state's record minimum temperature, -52C (-61F), was recorded 1 February 1985 at Maybell, Colorado. Maybell sits in the Yampa River valley in northwest Colorado, 48 km (30 mi) west of Craig (Figure 7) (CSU 2020).

In the high valley mountain town of Silverton (Figure 7), on the morning of 7 January 2020, the

minimum temperature in the lowest part of town (2,824 m (9,266 ft)) was -31C (-23F). On a hillside in town only 61 m (200 ft) above the lowest part of town, the minimum temperature was 12C (21F) warmer at -19C (-2F), and 488 m (1,601 ft) above the lowest part of town, the minimum temperature was, 20C (34F) warmer, at -11C (13F) (UCCS 2020) (Figure 14). Valley inversions can linger for a week or more (Whiteman, Bian, and Zhong 1999), trapping air pollution (Reddy, Barbarick, and Osterburg 1995) and creating persistent fog that interferes with air and ground transportation (Wolyn and McKee 1989).

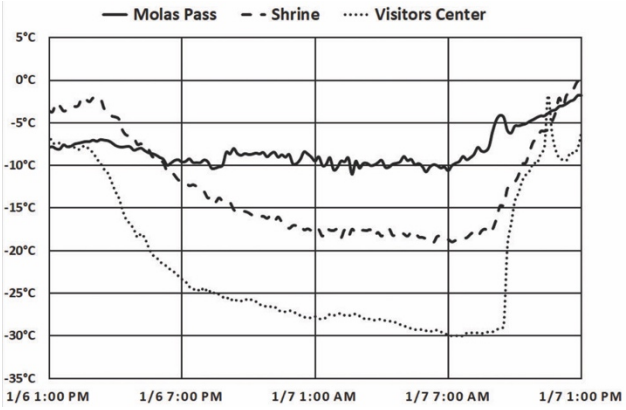

Figure 14. Cold air trapped under an inversion layer, Silverton, Colorado, 6-7 January 2020. Chart shows 24 hours of temperature change beginning 1:00 pm local time 6 January 2020 at three locations: 1) Molas Pass (solid line), a high point at 3,334 m (10,950 ft), 2) Shrine (dashed line), a hillside location in Silverton at 2,885 m (9,465 ft), and 3) Visitors Center (dotted line), the lowest elevation in Silverton, at 2,824 m (9,265 ft). The minimum temperature at the Visitors Center of -31C (-23F) is 20C (36F) colder than the minimum recorded 513 m (1,684 ft) higher at Molas Pass. The fact that the minimum temperature in the lowest part of town (Visitors Center) is 12C (21F) colder than the minimum temperature just 61 m (200 ft) above the valley floor (Shrine) indicates the shallow depth of the frigid air.

Conclusion

Storm systems become more tightly wound and stronger as they are stretched over Colorado's mountainous landscape. The Palmer Divide generates Colorado's hotspot for lightning activity (Hodanish, Vogt, and Wolyn 2019) and, via the DCVZ, energizes severe weather over the Denver metropolitan area. The NAM and ARs send copious moisture into the state where together, steep slopes and orographic processes develop soaking rains, frequent thunderstorms, flash flooding, and natural avalanche cycles. Sharp temperature and pressure fluctuations, hurricane force winds, blizzards, and extreme cold complement Colorado's meteorology. Other elements of the state's weather story include plowable hail, large hail, dust on snow, debris flows from burn scars, and flying saucer-shaped lenticular clouds.

Colorado's metropolitan areas flow up into the foothills of the Rocky Mountains, where precipitation is enhanced with steeper terrain. Encroachment into adjacent canyons and hillslope environs amplifies weather vulnerabilities, including those related to wildland fire and unchecked debris flows off burn scars (Cannon and DeGraff 2009). In context, Colorado's physical geography provides a wealth of opportunities to study and manage human-environment interactions.

Fittingly, an array of environmental, meteorological, and climatological research laboratories reside in Colorado: Boulder's National Center for Atmospheric Research (NCAR), University Corporation for Atmospheric Research (UCAR), Earth System Research Laboratory (ESRL), NOAA/ University of Colorado's (CU) Cooperative Institute for Research in Environmental Sciences (CIRES), and Fort Collins' Colorado State University (CSU)/ NOAA's Cooperative Institute for Research in the Atmosphere (CIRA).

A 2019 news story published in *OutThere Colorado* (McKee 2019) lists the "Top Eight Reasons No One Should Want to Move to Colorado." "Insane Weather" is number one. The author cites bomb cyclones, vehicles engulfed by avalanches, droughts, mudslides, 16-inch deep hail, and lightning strikes. Visitors and newcomers to Colorado likely perceive these extreme weather phenomena as outliers, whereas seasoned Coloradans prepare for and expect these conditions that, when melded with mountains, abundant sunshine, and low humidity, create Colorado's moderate and tenuously comfortable climate.

References

Achtor, T.H., and L.H. Horn. 1986. Spring season Colorado cyclones. Part I: Use of composites to relate upper and lower tropospheric wind fields. *Journal of Climate and Applied Meteorology* 25 (6):732-743.

Adams, D.K. and A.C. Comrie. 1997. The North American monsoon. *Bulletin of the American Meteorological Society* 78 (10):2197-2214.

Aguilar, J., and C. Brennan. 2013. Eight days, 1,000-year rain, 100-year flood. *Boulder Daily Camera.* September 21. Accessed January 1, 2020. https://

www.dailycamera.com/2013/09/21/eight-days-1000-year-rain-100-year-flood.

Alexander, M.A., J.D. Scott, D. Swales, M. Hughes, K. Mahoney, and C. A. Smith. 2015. Moisture pathways into the U.S. Intermountain West associated with heavy winter precipitation events. *Journal of Hydrometeorology* 16 (3):1184-1206.

Ashley, W.S., T.L. Mote, P.G. Dixon, S.L. Trotter, E.J. Powell, J.D. Durkee, and A.J. Grundstein. 2003. Distribution of mesoscale convective complex rainfall in the United States. *Monthly Weather Review* 131 (12):3003-3017.

Avery, B.A., C. N. Jones, J.D. Colton, and M.P. Meyers. 2002. A southwest Colorado mountain flash flood in an enhanced monsoonal environment. In *National Weather Digest*.

Banta, R. M. and C.B. Schaaf. 1987. Thunderstorm genesis zones in the Colorado Rocky Mountains as determined by traceback of geosynchronous satellite images. *Monthly Weather Review* 115 (2):463-476.

Cannon, S.H. and J. DeGraff. 2009. The increasing wildfire and post-fire debris-flow threat in western USA, and implications for consequences of climate change. In *Landslides–disaster risk reduction* (177-190). Springer, Berlin, Heidelberg.

Clark, J.H. 1990. An observational and theoretical study of Colorado lee cyclogenesis. *Journal of the Atmospheric Sciences* 47 (13):1541-1561.

Crook, N.A., T.L. Clark, and M.W. Moncrieff. 1990. The Denver cyclone. Part I: Generation in low Froude number flow. *Journal of the Atmospheric Sciences* 47 (23):2725-2742.

[CSU] Colorado State University. 2020. Colorado Climate Center state records. Accessed January1, 2020. https://climate. colostate.edu/ records.html.

[CSAS] Center for Snow and Avalanche Studies. 2017. Water Year 2017 Season summary. Accessed January1, 2020. http://www.codos.org/codosupdates/?offset=1517873167999.

[CW3E] Center for Western Weather and Water Extremes. 2019. Water Year 2019: March atmospheric rivers. Accessed January1, 2020. https://cw3e.ucsd.edu/water-year-2019-march-atmospheric-rivers.

Barnett, J. 2019. More than 46,000 customers in Denver area still without power a day after bomb cyclone whipped through Colorado. *Denver Post*, March 14. Accessed January1, 2020. https://www.denverpost.com/2019/03/14/denver-power-outages-thursday-bomb-cyclone.

Doesken, N.J., R.A. Pielke Sr., and O.A. P. Bliss. 2003. Climate of Colorado. Climatography of the United States, No. 60 (updated January 2003). Colorado Climate Center, Colorado State University, Fort Collins, CO.

Douglas, M.W., R.A. Maddox, K. Howard, and S. Reyes. 1993. The Mexican monsoon, *Journal of Climate* 6:1665-1677.

Durran, D. R. 2003. Downslope winds. *Encyclopedia of atmospheric sciences*, 1, pp. 644-650.

[ESRL] Earth System Research Laboratory 2020. Boulder wind information.. Accessed January1, 2020. https:// www.weather.gov/bou/highwind.

Gochis, D., R. Schumacher, K. Friedrich, N. Doesken, M. Kelsch, J, Sun, K. Ikeda, D. Lindsey, A. Wood, B. Dolan, et al. 2015. The great Colorado flood of September 2013. *Bulletin of the American Meteorological Society* 96 (9):1461-1487.

Godt, J.W. and J.A. Coe. 2007. Alpine debris flows triggered by a 28 July 1999 thunderstorm in the central Front Range, Colorado. *Geomorphology* 84 (1-2):80-97.

Hales, J.E. 1974. Southwestern United States summer monsoon source—Gulf of Mexico or Pacific Ocean? *Journal of Applied Meteorology* 13:331-342.

Hereford, R. and R.H. Webb. 1992. Historic variation of warm-season rainfall, southern Colorado Plateau, southwestern USA. *Climatic Change* 22 (3):239-256.

Higgins, R.W., Y. Yao, E.S. Yarosh, J.E. Janowiak, and K.C. Mo. 1997. Influence of the Great Plains low-level let on summertime precipitation and moisture transport over the central United States. *Journal of Climate* 10 (3):481–507.

Hodanish, S.J., B.J. Vogt, and P. Wolyn. 2019. Colorado lightning climatology. *Journal of Operational Meteorology* 7 (4):45-60.

Julian, L.T., and P.R. Julian. 1969. Boulder's winds. *Weatherwise* 22:108-112.

Krekeler, J. 2015. Central U.S. Winter Storm. Weather Prediction Center/National Centers for Environmental Prediction. Accessed January 1, 2020. https://www.wpc.ncep.noaa.gov/storm_summaries/event_reviews/2015/Central_US_WinterStorm_Nov2015.pdf.

Lilly, D.K., and E.J. Zipser. 1972. The front range windstorm of 11 January 1972 a meteorological narrative. *Weatherwise* 25 (2):56-63.

Maddox, R.A., K.W. Howard, D.L. Bartels, and D.M. Rodgers. 1986. Mesoscale convective complexes in the middle latitudes. In *Mesoscale Meteorology and Forecasting* (390-413). American Meteorological Society (AMS), Boston, MA.

McGinley, I. 1982. A diagnosis of alpine lee cyclogenesis. *Monthly Weather Review* 110:1271-1287.

McKee, S. Eight reasons no one should want to move to Colorado. OutThere Colorado. Accessed January 1, 2020. https://www.outtherecolorado.com/8-reasons-no-one-should-want-to-move-to-colorado.

Meyers, M.P., J.S. Snook, D.A. Wesley, and G.S. Poulos. 2003. A Rocky Mountain storm. Part II: The forest blowdown over the west slope of the northern Colorado mountains—Observations, analysis, and modeling. *Weather and Forecasting* 18 (4):662-674.

Najibi, N., N. Devineni, M. Lu, and R.A. Perdigão. 2019. Coupled flow accumulation and atmospheric blocking govern flood duration. *npj Climate and Atmospheric Science* 2 (1):19.

[NCDC] NOAA/National Climatic Data Center. 2004. Climatography of the United States. No. 20 1971–2000.

[NCEI] National Centers for Environmental Information. 2020. National Environmental Satellite, Data, and Information Service, Local Climatological Data Hourly Observations, January 8, 2015.

[NOAA] National Oceanic and Atmospheric Administration/Ocean Service. 2020. What is bombogenesis? Accessed February 2, 2020. https://oceanservice.noaa.gov/facts/bombogenesis.html.

[NOHRSC] National Operational Hydrologic Remote Sensing Center. 2020. Modeled Snow Depth Map for 17 November 2015. Accessed February 10, 2020. https://www.nohrsc.noaa.gov/interactive/html/map.html.

[NWS] NOAA/National Weather Service. 2019a. March 13th, 2019 "Bombogenesis" Event. Accessed January 1, 2020. https://www.weather.gov/pub/Bombogenesis_20190313.

———. 2019b. Top 12 Events of the 2010s in Colorado - #5 Colorado Avalanches in the Winter of 2019. Accessed January 1, 2020. https://www.weather.gov/gjt/ColoradoAvalanches_Winter2019.

———. 2019c. High Wind Safety. Accessed January 1, 2020. https://www.weather.gov/bou/highwind.

———. 2020. 2019 Climate Year in Review across Southern Colorado. Accessed January 1, 2020. https://www.weather.gov/pub/climate2019AnnualSummary.

Parker, 2002. Colorado Climate. Winter 2001 – 2002. 3(1). Colorado State University.

Petterssen, S. 1956. *Weather Analysis and Forecasting. Vol. 1 Motion Systems*. McGraw-Hill.

Ralph, F.M., M. Dettinger, J.M. Cordeira, J.J. Rutz, L. Schick, M. Anderson, D. Reynolds, L.J. Schick, and C. Smallcomb. 2019. A scale to characterize the strength and impacts of atmospheric rivers. *Bulletin of the American Meteorological Society* 100 (2):269–289.

Reddy, P.J., D.E. Barbarick, and R.D. Osterburg. 1995. Development of a statistical model for forecasting episodes of visibility degradation in the Denver metropolitan area. *Journal of Applied Meteorology* 34:616–625.

Rutz, J.J., W.J. Steenburgh, and F.M. Ralph. 2014. Climatological characteristics of atmospheric rivers and their inland penetration over the western United States. *Monthly Weather Review* 142 (2): 905-921.

Schaaf, C.B., J. Wurman, and R.M. Banta. 1988. Thunderstorm-producing terrain features. *Bulletin of the American Meteorological Society* 69 (3):272-277.

Schultz, D.M. and C.A. Doswell III. 2000. Analyzing and forecasting Rocky Mountain lee cyclogenesis often associated with strong winds. *Weather and Forecasting* 15 (2):152-173.

Smith, R., J. Paegle, T. Clark, W. Cotton, D. Durran, G. Forbes, J. Marwitz, C. Mass, J. McGinley, H.-L. Pan, and M. Ralph. 1997. Local and remote effects of mountains on weather: research needs and opportunities. *Bulletin American Meteorological Society* 78: 877-892.

Szoke, E.J. 1991. Eye of the Denver cyclone. *Monthly Weather Review* 119 (5):1283-1292.

Szoke, E.J., and J.A. Augustine. 1990. A decade of tornado occurrences associated with a surface mesoscale flow feature—The Denver Cyclone. Preprints, 16th Conference on Severe Local

Storms, Kananaskis Park, Alberta, Canada, American Meteorological Society, 554–559.

Szoke, E.J., and R. Rotunno. 1993. A comparison of surface observations and visual tornado characteristics for the June 15, 1988, Denver tornado outbreak. *American Geophysical Union Geophysical Monograph Series* 79:353-366.

Szoke, E.J., M.L. Weisman, J.M. Brown, F. Caracena, and T.W. Schlatter. 1984. A subsynoptic analysis of the Denver tornadoes of 3 June 1981. *Monthly Weather Review* 112 (4):790-808.

Tang, M., and E.R. Reiter. 1984. Plateau monsoons of the Northern Hemisphere: A comparison between North America and Tibet. *Monthly Weather Review* 112: 617-637.

Tripoli, G.J. 1986. A numerical investigation of an orogenic mesoscale convective system. PhD diss., Colorado State University.

Tucker, D.F. and N.A. Crook. 2005. Flow over heated terrain. Part II: Generation of convective precipitation. *Monthly Weather Review* 133: 2565-2582.

[UCCS] University of Colorado Colorado Springs. 2020. D. Anderson, J. Buchheit, L. Hare, R. Johnson, K. Kuyper, B. Lamb, M. Learned, N. Luther, E. Meshkov, C. Silverstein, M. Varner, K. Zito, and B. Vogt. "Documenting a Valley Inversion." Hobo and TidBit Temperature Data Collection Campaign. Field Studies: Snowpack Assessment, Silverton, Colorado: Geography and Environmental Studies GES4460. (Associate Professor Brandon Vogt). January 2020.

Vogt, B., and S. Hodanish. 2016. A geographical analysis of warm season lightning/landscape interactions across Colorado, USA. *Applied Geography* 75:93-105.

Vogt, B., and S. Hodanish. 2014. A high resolution lightning map of the state of Colorado. *Monthly Weather Review* 142 (7):2353-2360.

Wetzel, P.J., W.R. Cotton, and R.L. McAnelly. 1983. A long-lived mesoscale convective complex. Part II: Evolution and structure of the mature complex. *Monthly Weather Review* 111 (10):1919-1937.

Whiteman, C.D., and J.G. Whiteman. 1974. An historical climatology of damaging downslope windstorms at Boulder, Colorado. NOAA Tech. Report ERL 336-APCL 35. Available from the Superintendent of Documents, U.S. Government Printing Office, Washington D.C.

Whiteman, C.D., X. Bian, and S. Zhong. 1999. Wintertime evolution of the temperature inversion in the Colorado Plateau Basin. *Journal of Applied Meteorology* 38 (8):1103-1117.

Whittaker, L.M., L.H. Horn. 1981. Geographical and seasonal distribution of North American cyclogenesis, 1958-1977. *Monthly Weather Review* 109:2312-2322.

Wilson, J.W., J.A. Moore, G.B Foote,B. Martner, A.R. Rodi, T. Uttal. and J.M. Wilczak. 1988. Convection initiation and downburst experiment (CINDE). *Bulletin of the American Meteorological Society* 69 (11):1328-1347.

Wolyn, P.G. and T.B. McKee. 1989. Deep stable layers in the intermountain western United States. *Monthly Weather Review* 117 (3):461-472.

Yochum, S.E., J.A. Scott, and D.H. Levinson. 2019. Methods for assessing expected flood potential and variability: Southern Rocky Mountains region. *Water Resources Research* 55 (8):6392-6416.

Zielinski, G.A. and B.D. Keim. 2003. Northeast Weather, Northeast Climate. University of Maine.

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QUAKING ASPEN: THE ICONIC AND DYNAMIC DECIDUOUS TREE OF THE ROCKY MOUNTAINS

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Introduction

Perhaps no other species of tree jumps to mind as quickly as Quaking aspen (*Populus tremuloides* Michx.) when one waxes poetically about the iconic vistas of the Rocky Mountain West. Quaking aspen, so called for its trembling leaves, have been the focus of countless paintings and photographs, from Ansel Adams to John Fielder to scores of amateur photographers whose hashtags identify the species on Instagram. The ecological setting of many upland aspen settings provides a sharp contrast against exposed rock, snow and the dark green blanket of conifer forests that many of us seek out in the autumn. Such scenes drive tourism revenue and are used in many recreational activity advertisements by western resorts. Beyond their aesthetic value, aspen communities are valued for the biological diversity and habitat they provide in western landscapes. Furthermore, aspen face a number of ecological and management challenges that likely go unnoticed by the tourist or casual recreator. Above all, aspen communities are dynamic, so there is a good chance your favorite aspen grove might look different at some point in your lifetime. The goal of this essay is to provide a broad overview of the unique niche of aspen ecosystems in the interior Rocky Mountain West, highlight its dynamic nature, and shed light on the challenges associated with stewardship of this iconic species.

Aspen Biogeography

Quaking aspen, the most widely distributed deciduous tree in North America, are largely limited to mountainous areas, high plateaus and riparian zones in the West where moisture, soil and topography provide a favorable setting (Bartos 2001) (Figure 1). The total aspen organism is more than meets the eye, as aspen are clonal in nature, with many trees often sharing the same root system. Individual aspen trees or aboveground shoots are known as ramets. Ramets that are connected together through underground roots share the same genotype and are known as a genet (DeByle 1985) (Figure 2).

Figure 1. The potential distribution of aspen in the western United States (Little 1971).

Figure 2. Retired U.S. Forest Service Ecologist, Bob Campbell, displays the rhizome or underground root that connects two aspen shoots known as ramets. Photo by the author.

The characteristic white bark of aspen is unique in that, unlike most trees, it is living tissue, capable of stem photosynthesis that contributes significantly to aspen's over-wintering survival capabilities (Berveiller, Kierzkowski, and Damesin 2007).

Aspen reproduction by vegetative suckering is much more common than sexual reproduction via pollination, fertilization, seed development, seed dispersal and finally seed germination (Bartos 2001). During normal growth, the hormone auxin found in the canopy of aspen suppresses vegetative suckering that is triggered by cytokinin, a root hormone. However, when a disturbance removes the canopy or some portion of it, the auxin-cytokinin hormone ratio changes. An increase in the balance of cytokinin induces suckering and aspen are able to quickly regrow, effectively outcompeting most other species for some period of time after a disturbance (Bartos 2001). Clones vary in size and are capable of growing quite large in the western United States. In south-central Utah, scientists have measured one aspen stand that is nearly 180,000 m^2 (one genet) and estimated to contain over 44,000 stems (ramets) (Kemperman and Barnes 1976; DeWoody et al. 2008). It is known as the "Pando clone" and potentially represents the largest living organism on Earth (Rogers et al. 2014). The large size of western aspen clones is likely a result of older stands that have vegetatively propagated from suckering after fire. Initiation of new clones through sexual reproduction is thought to be rare in the Rocky Mountain region over the last several thousand years due to suboptimal climate conditions (Romme et al. 2001). Although documentation of sexual regeneration from seed is rare, it may be a more widespread trait than previously recognized, as advances in genetic research suggest sexual reproduction is a stronger contributor to aspen genetic variation than previously thought (Elliott and Baker 2004; Mock et al. 2008). There is a research need to address the question of sexual regeneration that produces aspen seedling recruitment events: are these a brief post-fire phenomenon, or will these populations achieve tree status, produce new ramets, and develop into functioning aspen stands (Turner et al. 2003)?

There are generally two functional types of aspen systems, seral and stable, with several sub-types of each (Rogers et al. 2014). Aspen in seral systems typically occur with coniferous trees and the dominance is governed by the time since the last stand-replacing disturbance. After a disturbance, aspen resprout from root systems and might dominate a stand for several decades, or even a century, before conifer species eventually overtake aspen trees (Shinneman et al. 2013). Conversely, in stable communities, aspen maintain dominance for extended periods (> 100 years) with incremental stand replacement (Kashian, Romme, and Regan 2007; Kurzel, Veblen, and Kulakowski 2007).

Why is aspen important?

Biodiversity

Aspen communities provide a number of ecosystem services that may not be obvious to the casual observer. Although they only occupy small portions of the western landscape, aspen stands contribute disproportionately to plant and animal diversity, making these forests hotspots of biodiversity (Figure 3). Many more species of birds, mammals, and invertebrates are found in aspen stands than in conifer dominated forests, including a disproportionate number of vascular plant species (Chong et al. 2001; DeByle 1985). It is not surprising that aspen forests provide high value forage for native ungulates including, elk, moose and deer (DeByle 1985).

Social Values

Aspen are a broad-leaf deciduous species that drop their leaves each autumn. The seasonal phenology, or timing of biological events, associated with aspen stands are what sets them apart from so many other elements on the landscape, especially their evergreen, coniferous neighbors (Assal, Anderson, and Sibold 2015). The phenomenon of leaf senescence is a major reason why so many people value aspen for aesthetic reasons. Early autumn is a great time to get a sense of the spatial extent of aspen clones as leaves of genets, with their single, connected root system, typically turn color at the same time. The leaves of neighboring genets often senesce at slightly different times, creating the kaleidoscope of color that so many of us seek to capture in photographs each autumn. In addition to aesthetic reasons, many of us seek refuge in and around aspen as part of our outdoor experience be it skiing, camping, hiking or hunting. Many of these experiences contribute to economic benefits of state and local businesses, including hunting licenses, which benefit funding of state wildlife agencies (Rogers 2017).

Figure 3. Sapsuckers, a species of woodpecker, create holes in aspen bark to create sap wells (top; Steamboat Mountain, WY), the base of an aspen tree provides a substrate for lichen (center; Wind River Range, WY), moose congregate at the edge of a riparian aspen stand (bottom; Bighorn Mountains, WY). Photos by the author.

Forage for Domestic Livestock

Aspen forests provide high value forage for domestic livestock (DeByle 1985) and livestock producers have long depended on the diversity and biomass of aspen understory communities to feed their cattle and sheep. Aspen are found at higher elevations in the West, and provide for herds during hot dry winter months (Bartos 2001). Given this land use, ranchers receive a direct economic benefit from aspen, as well as the indirect benefits to their home municipalities (Rogers 2017), although these are rarely quantified.

Aspen Dynamics

Disturbance plays a prominent role in shaping the vegetation of western landscapes. A disturbance is a relatively discrete event that changes the resource availability or physical environment which shapes forest ecosystems by influencing their composition, structure, and functional processes (White and Pickett 1985). Forests of the Rocky Mountain region are molded by their history of disturbance and prior land-use (Dale et al. 2001) and this plays a large part in the dynamic nature of aspen ecosystems. Seral aspen are often considered a disturbance driven species, as stands quickly resprout from root systems following a disturbance. Forest disturbances are both human-induced and natural, although humans are capable of influencing natural processes. The major disturbance types of aspen forests include fire, climate change/drought, insect/fungal agents, while ungulate herbivory is a primary stressor of regeneration. For the purposes of this discussion, management treatments are included here although they do not always have the same effect as natural disturbances (due to size, severity, frequency, etc.).

Fire

Fire is widely recognized as one of the main disturbance drivers in aspen ecosystems (Romme et al. 2001); however, few fire history studies have been conducted that are specific to aspen dominated forests (Kulakowski, Veblen, and Kurzel 2006). The main difficulty reconstructing fire history in aspen forests is that trees are easily killed by fire and few fire-scarred trees can be found to date past fires (Romme et al. 2001). Fire frequency and severity differs with elevation and location. In western Colorado, high elevation subalpine forests experience infrequent stand-replacing fires, whereas, woodlands and shrublands typically experience more frequent fires

(Kulakowski, Veblen, and Kurzel 2006; Sibold, Veblen, and Gonzalez 2006). Given their clonal nature, aspen are able to outcompete conifers and other species that do not have the ability to resprout after disturbance.

Climate Change & Drought

Climate projections over the next century indicate aspen habitat will be reduced in western North America (Rehfeldt, Ferguson, and Crookston 2009), largely as a result of increased drought and heat stress (Allen et al. 2010). Productivity is limited by carbon dioxide fixation imposed by leaf stomatal resistance during soil or atmospheric water deficits and photosynthetic productivity is greatly reduced (Hogg, Brandt, and Michaelian 2008). Recent drought events have caused widespread aspen mortality (Michaelian et al. 2011; Worrall et al. 2008) and low elevation aspen forests along the forest-shrubland ecotone are particularly vulnerable to drought (Assal, Anderson, and Sibold 2016) (Figure 4). Furthermore, trees that are not killed during a drought experience hydraulic deterioration, which damages the xylem, leaving surviving trees more vulnerable to future drought and other stressors (Anderegg et al. 2013). The frequency of drought events in the western United States is expected to increase in the future (Dale et al. 2001) and represents a likely pathway for climate change to fundamentally alter the composition, structure, and biogeography of aspen forests in many regions (Anderegg et al. 2013).

Fungal and Insect Damaging Agents

Aspen are susceptible to a number of fungal diseases and insects that can damage plants and reduce the health and vigor of aspen stands (Shepperd et al. 2006). Fungal canker diseases attack and girdle aspen trees, root diseases found in the soil weaken plants, and several insect species defoliate aspen trees. Each of these agents are capable of killing individual trees, although widespread disease and/or repeated defoliation events can cause stand level mortality (Shepperd et al. 2006). The outbreak of mountain pine beetle (*Dendroctonus ponderosae*) in northcentral Colorado represents an interesting case for aspen forests. Mountain pine beetle outbreaks have caused widespread conifer mortality in western North American since the late 1990s (Raffa et al. 2008). Although aspen are not entirely congruent with the range of these conifer species, this represents an opportunity for aspen expansion and is an area of needed research (Pelz and Smith 2013).

Figure 4. A low elevation stand with high levels of mortality from recent drought (Middle Mountain, CO). Photo by the author.

Ungulate Herbivory

Domestic livestock (sheep, cattle) and wild ungulates (moose, elk, and deer) both consume young, regenerating aspen plants that can have long-term effects on the viability of the stand. Heavy and uncontrolled grazing by domestic livestock was widespread during the first half of the 20th century and effects of this time period likely linger (DeByle 1985). Herbivory by native ungulates can also have major implications on aspen regeneration and survival, especially in the animal's winter ranges. Aspen cohorts in Rocky Mountain National Park only regenerated over the last century when elk populations on the winter range were low (Baker, Munroe, and Hessl 1997). Likewise, in western Wyoming, periods of low to moderate elk populations corresponded with frequent aspen ramet regeneration (Hessl and Graumlich 2002). Other studies in the West found high browse pressure reduced stand growth but did not preclude stand-replacing regeneration across elk winter ranges (Barnett and Stohlgren 2001; Kaye, Binkley, and Stohlgren 2005). Nevertheless, high browse pressure is a major concern on aspen regeneration dynamics. Browsing reduces sapling growth, vigor and abundance, particularly when terminal buds are removed, resulting in stunted growth (Kaye, Binkley, and Stohlgren 2005). A browse line is often visible in stands with high browse pressure, indicative of little regeneration (Figure 5).

Figure 5. Heavy bark damage and no regeneration indicate high ungulate use in this stand (Sierra Madre Mountains, WY). Photo by the author.

Management Treatments

A number of management techniques are used to change the hormonal balance of an aspen stand to promote a flush of suckering and regrowth (Bartos 2001; Shepperd et al. 2006) (Figure 6). Mechanical treatments which remove the majority of above-ground vegetation, but leave the root systems intact, are commonly used (Shepperd et al. 2006). Prescribed fire (Bartos, Brown, and Booth 1994; Shinneman et al. 2013) and removal of competing vegetation in a stand, typically large conifers, are also employed as management techniques (Bowen et al. 2010).

Long-term Trends

The scientific literature on long-term trends is not conclusive regarding the expansion or contraction of aspen across any given region of its range in western North America (Rogers, Eisenberg, and St. Clair 2013; Kashian, Romme, and Regan 2007). Some studies have concluded aspen is in decline, largely as a result of changes in the fire regime, herbivore population and climate (Baker, Munroe, and Hessl 1997; Bartos 2001; Di Orio, Callas, and Schaefer 2005; Kay 1997). However, other studies have found expansion (Kulakowski, Veblen, and Kurzel 2006) or both expansion and contraction in the same area (Brown et al. 2006; Kashian, Romme, and Regan 2007). A growing number of studies suggest the temporal scale of study be expanded beyond the 20th century to consider the full range of variability of climate conditions and fire regime found across aspen communities (Barnett and Stohlgren 2001; Kulakowski, Veblen, and Kurzel 2006; McIlroy and Shinneman 2020). In addition, localized studies are not always appropriate to extrapolate to regional trends (Brown et al. 2006) and multiple spatial scales should be incorporated where possible (McIlroy and Shinneman 2020). Variable ecological conditions affect community dynamics and long-term aspen resilience for a given aspen functional type in different ways (Rogers et al. 2014). However, these divergent viewpoints shed light on the complexity of aspen ecology, stewardship and conservation across the West (Rogers, Eisenberg, and St. Clair 2013).

Management Challenges

Aspen are of great concern for many state and federal agencies charged with managing viable populations; however, a number of factors make the stewardship of this species incredibly difficult. Climate warming, herbivory and inappropriate management are the biggest threats to aspen resilience (Rogers et al. 2014). Although aspen is adept at vegetative reproduction, it is a sexually challenged species and may only be able to sexually regenerate (from seed set through establishment of mature stands) in very favorable climates (Turner et al. 2003; Romme et al. 2001). We do not know the age of the genets on our landscapes, but they were likely established during a cooler and wetter climate. Vegetative reproduction is a very effective strategy to recolonize areas after disturbance, but it poses challenges to migration if climate profiles shift to higher elevations as a result of climate change. In an uncertain future, Aspen's strategy will be tested.

Managers must decide where and when to conduct treatments with limited resources and diverse aspen functional types require a targeted management prescription (Rogers et al. 2014). Although aspen typically respond positively to treatments, the herbivory pressure is so great in some areas that it could preclude young aspen saplings from growing out of the browse zone and developing into mature trees to sustain a stand. Managers face logistical challenges to appease multiple stakeholders, as a substantial amount of aspen occur on lands managed by numerous federal and state agencies, including private lands. Yet another concern is conducting active management in high profile areas that will change the landscape for many camera-toting

Figure 6. A prescribed burn was applied to this aspen stand several decades ago. Dense regeneration has occurred where higher severity fire induced greater mortality (Little Mountain, WY). Photo by the author.

tourists of today in an effort to ensure aspen are maintained on that landscape.

Conclusion

Although aspen face many ecological and management challenges, these provide a great opportunity for scientists and managers to work alongside each other to conduct applied science to guide management of these systems. Indeed, these needs have galvanized both communities over the last couple of decades to work toward a common goal of aspen resilience through dedicated conferences (see proceedings associated with (Bartos 2001)), special journal issues (Rogers, Eisenberg, and St. Clair 2013) and field workshops (Figure 7). We often forget the vegetation of a given landscape is dynamic, with a number of forces acting to re-shape and reorganize it as we move into an uncertain future. Our viewpoint is nearly a snapshot. Take a moment to think about the history of the landscape when you line up your next iconic photo of quaking aspen, and remember, it could look very different in the future.

Figure 7. Paul Rogers, Western Aspen Alliance and Utah State University, discusses aspen regeneration during an "Aspen Days" workshop sponsored by the Wyoming Game and Fish Department. Photo by the author.

References

Allen, C. D., A. K. Macalady, H. Chenchouni, D. Bachelet, N. McDowell, M. Vennetier, T. kitzberger, et al. 2010. a global overview of drought and heat-induced tree mortality reveals emerging climate change risks for forests. *Forest Ecology and Management* 259 (4):660–84. doi:10.1016/j.foreco.2009.09.001.

Anderegg, W. R. L., L. Plavcová, L. D. L. Anderegg, U. G. Hacke, J. A. Berry, and C. B. Field. 2013. Drought's legacy: Multiyear hydraulic deterioration underlies widespread aspen forest die-off and portends increased future risk. *Global Change Biology* 19 (4):1188–96. doi:10.1111/gcb.12100.

Assal, T. J., P.J. Anderson, and J. S. Sibold. 2016. Spatial and temporal trends of drought effects in a heterogeneous semi-arid forest ecosystem. *Forest Ecology and Management* 365:137–51. doi:10.1016/j.foreco.2016.01.017.

———. 2015. Mapping forest functional type in a forest-shrubland ecotone using SPOT imagery and predictive habitat distribution modelling. *Remote Sensing Letters* 6 (10):755–64. doi:10.1080/2150704X.2015.1072289.

Baker, W. L., J. A. Munroe, and A. E. Hessl. 1997. The effects of elk on aspen in the Winter Range in Rocky Mountain National Park. *Ecography* 20 (2):155–65.

Barnett, D. T., and T. J. Stohlgren. 2001. Aspen persistence near the National Elk Refuge and Gros Ventre Valley Elk Feedgrounds of Wyoming , USA. *Landscape Ecology* 16:569–80.

Bartos, D. L., 2001. Landscape dynamics of aspen and conifer forests. In *Sustaining aspen in western landscapes: Symposium proceedings*; 13–15 June 2000; Grand Junction, CO. Proceedings RMRS-P-18, ed. W.D. Shepperd, D. Binkley, D.L. Bartos, T.J. Stohlgren, L.G. Eskew, 5-14. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Bartos, D. L., J. K. Brown, and G. D. Booth. 1994. Twelve years biomass response in aspen communities following fire. *Journal of Range Management* 47 (1):79–83. doi:10.2307/4002846.

Berveiller, D., D. Kierzkowski, and C. Damesin. 2007. Interspecific variability of stem photosynthesis among tree species. *Tree Physiology* 27 (1):53–61. doi:10.1093/treephys/ 27.1.53.

Bowen, Z. H., C. L. Aldridge, P. J. Anderson, T. J. Assal, L. R. H. Biewick, S. W. Blecker, S. Briston, N. B. Carr, A. D. Chalfoun, G. W. Chong, et al. 2010. U.S. Geological Survey science for the Wyoming Landscape Conservation Initiative—2009 annual report. Reston, Virginia. https://pubs.usgs.gov/of/2010/1231/.

Brown, K., A. J. Hansen, R. E. Keane, and L. J. Graumlich. 2006. Complex interactions shaping aspen dynamics in the Greater Yellowstone ecosystem. *Landscape Ecology* 21 (6):933–51. doi:10.1007/s10980-005-6190-3.

Chong, G. W., S. E. Simonson, T. J. Stohlgren, and M. A. Kalkhan. 2001. Biodiversity: Aspen stands have the lead , but will nonnative species take over? In *Sustaining aspen in western landscapes: Symposium proceedings*; 13–15 June 2000; Grand Junction, CO. Proceedings RMRS-P-18, ed. W. D. Shepperd, D. Binkley, D. L. Bartos, T. J. Stohlgren, L. G. Eskew, 261-272. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Dale, V. H., L. A. Joyce, S. Mcnulty, R. P. Neilson, M. P. Ayres, M. D. Flannigan, P. J. Hanson, et al. 2001. Climate change and forest disturbances. *BioScience* 51 (9):723–34. doi:10.1641/0006-3568(2001)051.

DeByle, N. V. 1985. Animal impacts. In *Aspen: ecology and management in the western United States*, ed. DeByle, N.V., R.P. Winokur, 115–123. Fort Collins, CO: USDA Forest Service General Technical Report RM-119.

DeWoody, J., C.A. Rowe, V.D. Hipkins, and K.E. Mock. 2008. "Pando" lives : Molecular genetic evidence of a giant aspen clone in central Utah. *Western North American Naturalist* 68 (4):493–97.

Elliott, G.P., and W.L. Baker. 2004. Quaking aspen (*Populus tremuloides Michx*.) at treeline: A century of change in the San Juan Mountains, Colorado, USA. *Journal of Biogeography* 31 (5): 733–45. doi:10.1111/j.1365-2699.2004.01064.x.

Hessl, A. E., and L. J. Graumlich. 2002. Interactive effects of human activities, herbivory and fire on quaking aspen (*Populus tremuloides*) age structures in western Wyoming. *Journal of Biogeography* 29 (7):889–902. doi:10.1046/j.1365-2699.2002.00703.x.

Hogg, E. H., J. P. Brandt, and M. Michaelian. 2008. Impacts of a regional drought on the productivity, dieback, and biomass of western Canadian aspen forests. *Canadian Journal of Forest Research* 38 (6):1373–84. doi:10.1139/X08-001.

Kashian, D. M., W. H. Romme, and C. M. Regan. 2007. Reconciling divergent interpretations of quaking aspen decline on the northern Colorado Front Range. *Ecological Applications* 17 (5): 1296–1311.

Kay, C. E. 1997. Is aspen doomed? *Journal of Forestry* 95:4–11.

Kaye, M. W., D. Binkley, and T. J. Stohlgren. 2005. Effects of conifers and elk browsing on quaking aspen forests in the central Rocky Mountains, USA. *Ecological Applications* 15 (4):1284–95.

Kemperman, J., and B. Barnes. 1976. Clone size in American aspens. *Canadian Journal of Botany* 54 (22):2603–7.

Kulakowski, D., T. T. Veblen, and B. P. Kurzel. 2006. Influences of infrequent fire, elevation and pre-

fire vegetation on the persistence of quaking aspen (*Populus tremuloides Michx*.) in the Flat Tops Area, Colorado, USA. *Journal of Biogeography* 33 (8):1397–1413. doi:10.1111/j.1365-2699.2006.01529.x.

Kurzel, B. P., T. T. Veblen, and D. Kulakowski. 2007. A typology of stand structure and dynamics of quaking aspen in northwestern Colorado. *Forest Ecology and Management* 252 (1–3):176–90. doi:10.1016/j.foreco.2007.06.027.

Little, E. L. 1971. Atlas of the United States Trees, Volume 1, Conifers and Important Hardwoods. USDA Forest Service Miscellaneous Publication 1146, Washington, DC.

McIlroy, S. K., and D. J. Shinneman. 2020. Post-fire aspen (*Populus tremuloides*) regeneration varies in response to winter precipitation across a regional climate gradient. *Forest Ecology and Management* 455:117681. doi:10.1016/j.foreco.2019.117681.

Michaelian, M., E. H. Hogg, R. J. Hall, and E. Arsenault. 2011. Massive mortality of aspen following severe drought along the southern edge of the Canadian boreal forest. *Global Change Biology* 17 (6):2084–94. doi:10.1111/j.1365-2486.2010.02357.x.

Mock, K. E., C. A. Rowe, M. B. Hooten, J. Dewoody, and V. D. Hipkins. 2008. Clonal dynamics in western North American aspen (*Populus tremuloides*). *Molecular Ecology* 17 (22):4827–44. doi:10.1111/j.1365-294X.2008.03963.x.

Orio, A. P. Di, R. Callas, and R. J. Schaefer. 2005. Forty-eight year decline and fragmentation of aspen (*Populus tremuloides*) in the South Warner Mountains of California. *Forest Ecology and Management* 206 (1–3):307–13. doi:10.1016/j.foreco.2004.11.011.

Pelz, K. A., and F. W. Smith. 2013. How will aspen respond to mountain pine beetle? A review of literature and discussion of knowledge gaps. *Forest Ecology and Management* 299:60–69. doi:10.1016/j.foreco.2013.01.008.

Raffa, K. F., B. H. Aukema, B. J. Bentz, A. L. Carroll, J. A. Hicke, M. G. Turner, and W. H. Romme. 2008. Cross-scale drivers of natural disturbances prone to anthropogenic amplification: The dynamics of bark beetle eruptions. *BioScience* 58 (6):501–17. doi:10.1641/B580607.

Rehfeldt, G. E., D. E. Ferguson, and N. L. Crookston. 2009. Aspen, climate, and sudden decline in western USA. *Forest Ecology and Management* 258 (11):2353–64. doi:10.1016/j.foreco.2009.06.005.

Rogers, P. C., S. M. Landhausser, B. D. Pinno, and R. J. Ryel. 2014. A functional framework for improved management of western North American aspen (*Populus tremuloides Michx*.). *Forest Management* 60 (2):345–59.

Rogers, P. C. 2017. Guide to quaking aspen ecology and management with emphasis on Bureau of Land Management Lands in the Western United States. BLM-UT-G1017-001-8000. U.S. Department of Interior, Bureau of Land Management, Logan, UT.

Rogers, P. C., C. Eisenberg, and S. B. St. Clair. 2013. Resilience in Quaking Aspen: Recent advances and future needs. *Forest Ecology and Management* 299:1–5. doi:10.1016/j.foreco.2012.11.008.

Romme, W. H., L. Floyd-Hanna, D. D. Hanna, and E. Bartlett. 2001. Aspen's ecological role in the West. In In *Sustaining aspen in western landscapes: Symposium proceedings*; 13–15 June 2000; Grand Junction, CO. Proceedings RMRS-P-18, ed. W.D. Shepperd, D. Binkley, D.L. Bartos, T.J. Stohlgren, L.G. Eskew, 243-260. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Shepperd, W. D., P. C. Rogers, D. Burton, and D. L. Bartos. 2006. Ecology, biodiversity, management, and restoration of aspen in the Sierra Nevada, RMRS-GTR- 178. Rocky Mountain Research Station, USDA, Forest Service, Fort Collins, CO.

Shinneman, D. J., W. L. Baker, P. C. Rogers, and D. Kulakowski. 2013. Fire regimes of Quaking Aspen in the mountain West. *Forest Ecology and Management* 299:22–34. doi:10.1016/ j.foreco.2012.11.032.

Sibold, J. S., T. T. Veblen, and M. E. Gonzalez. 2006. Spatial and temporal variation in historic fire regimes in subalpine forests across the Colorado Front Range in Rocky Mountain National Park, Colorado, USA. *Journal of Biogeography* 33 (4):631–47. doi:10.1111/j.1365-2699.2005.01404.x.

Turner, M. G., W. H. Romme, R. A. Reed, and G. A. Tuskan. 2003. Post-fire aspen seedling recruitment across the Yellowstone (USA) land-scape. *Landscape Ecology* 18:127–40.

White, P. S., and S. T. A. Pickett. 1985. Natural disturbance and patch dynamics: An introduction.

In *The Ecology of Natural Disturbance and Patch Dynamics*, 3–13. New York, NY: Academic Press.

Worrall, J. J., L. Egeland, T. Eager, R. A. Mask, E. W. Johnson, P. A. Kemp, and W. D. Shepperd. 2008. Rapid mortality of *Populus tremuloides* in southwestern Colorado, USA. *Forest Ecology and Management* 255 (3–4):686–96. doi:10.1016/j. foreco. 2007.09.071.

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THE SOUTH PLATTE RIVER RIPARIAN FOREST IN EASTERN COLORADO

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Introduction: The South Platte River Today

The South Platte River arises in the Mosquito Range near South Park, in central Colorado, and flows approximately 725 km (450 miles) across northeastern Colorado (Figure 1). The South Platte River watershed is 62,937 km^2 (24,300 miles^2), of which approximately 25% occurs in the Southern Rocky Mountain physiographic province and 75% occurs in the Great Plains (Dennehy et al. 1993). Key tributaries are Clear Creek, Saint Vrain Creek, Big Thompson River and Cache la Poudre River, all perennial streams that drain mountain watersheds. Several ephemeral streams that arise on the plains also contribute water to the South Platte River in some years (e.g., Kiowa Creek, Bijou Creek, and Beaver Creek). The North Platte River joins the South Platte River in Nebraska, to form the Platte River, which itself is a tributary of the Missouri River.

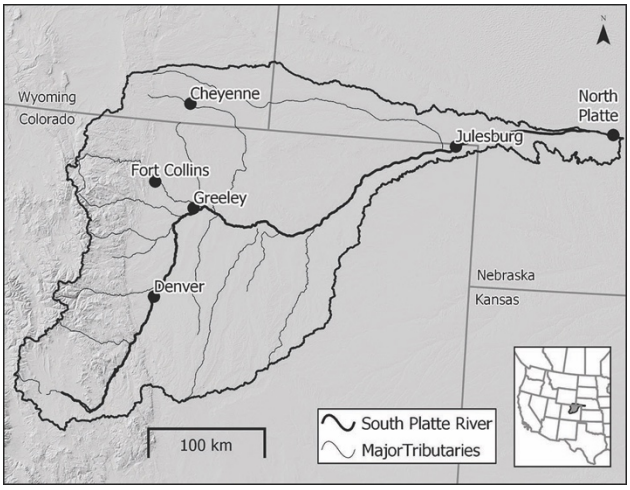

Figure 1. South Platte River Basin.

The South Platte River watershed contains the Denver metropolitan area, as well as much of the entire Front Range urban corridor, which is the economic engine of Colorado. The population of the South Platte River basin was 3.7 million in 2015 (comprising 70% of Colorado's population), and is projected to reach 6 million by 2050. The majority of the watershed area, however, is rural; land use is dominated by rangeland and cultivated agriculture, with urban areas comprising less than 3% of land cover in the basin (Dennehy et al. 1993). Thus, the South Platte River and its tributaries comprise the primary water supply for a large metropolitan region, as well as for agricultural uses in much of northeastern Colorado. With explosive urban population growth occurring in the basin and climate change predicted to result in less available water, issues of water demand are paramount, and considerable attention is focused on how to meet the anticipated water supply gap (SPBRT/MBRT 2015). The river corridor is also a cherished environmental amenity in Colorado, providing recreational opportunities (e.g., whitewater rafting, fishing, hunting, greenways, etc.), as well as aesthetic values (e.g., enjoyment of nature, wildlife viewing, etc.) for Colorado residents and tourists alike.

The South Platte River floodplain today is dominated by human land use—crop agriculture and grasslands that are used primarily for rangeland. In a GIS study of aerial photographs of a 30-km section of the South Platte River floodplain in Logan County, Colorado, we found that in 2015 the floodplain was approximately 38% crop agriculture, 23% riparian forest, 14% grassland, 9% wetland meadow, and 9% active channel (including surface water and sparsely vegetated sand bars), with barren areas, development, reservoirs, and riparian shrublands each comprising approximately 2% of floodplain land cover (Salo and Katz, unpublished data). Similar analyses for river sections upstream indicated that the proportion of the floodplain used for crop agriculture increases in the downstream direction, while grassland decreases.

Downstream of Denver, the South Platte River supports a broad riparian gallery forest (Figure 2), which constitutes a unique landscape element in a region otherwise typified by grassland vegetation.

The forest is dominated by plains cottonwood (*Populus deltoides*) and peachleaf willow (*Salix amygdaloides*), both native species to Colorado. Cottonwood comprises approximately 80% of forest basal area, while peachleaf willow comprises close to 12% (Katz and Norton, unpublished data). The South Platte River riparian forest is a valued natural resource, providing important ecosystem services such as storage of floodwaters, groundwater recharge, water quality enhancement, wildlife habitat, and recreation opportunities (Strange, Fausch, and Covich 1999). As a testament to the ecological value of this ecosystem, Colorado Parks and Wildlife operates more than 20 State Wildlife Areas on the South Platte River and key tributaries east of the foothills. On the other hand, as Colorado seeks to meet growing municipal water demand in the South Platte River basin, "non-beneficial" water use by riparian ecosystems has been scrutinized (Waskom 2013, SPBRT/MBRT 2015).

Figure 2. Aerial view of the South Platte River northeast of Kersey, Colorado, June 3, 2013 (copyright 2013 William A. Cotton/CSU Photography).

The South Platte River riparian forest owes its existence to the unique combination of hydrology, geomorphology, and human history that characterize this river system. Unlike many rivers in western North America, water management on the South Platte River has resulted in a vibrant forest ecosystem dominated by native cottonwoods and willows. The history of forest development thus reflects the history of anthropogenic water management. Understanding the history of this forest, and its likely future trajectory, requires an understanding the ecology of native riparian trees.

Riparian Forest Ecology

In arid and semi-arid regions of western North America, cottonwoods and willows are native, riparian pioneer species whose ecology is strongly linked to fluvial disturbance processes and hydrology. Cottonwood and willow seedlings have high moisture requirements, are intolerant of shade, and generally do not establish within intact existing vegetation. Because of these constraints, in any given year cottonwood and willow seedlings usually become established adjacent to, or within, the active zone of the river channel where bare moist substrate is available for colonization (Friedman et al. 1997). However, mortality rates of close to 100% are commonly observed for cottonwood and willow seedlings established in the active channel zone, due to summer drought stress during their first growing season, or to prolonged inundation, complete burial by sediment, or lethal scouring by water or ice during subsequent flows. For example, Sedgwick and Knopf (1989) found a 99% decrease in cottonwood seedling densities on the South Platte River from June to September 1984, a year with average precipitation and discharge.

In order for cottonwood and willow seedling establishment to lead to longer term survival and recruitment into older age classes, seedlings must have adequate moisture but also be protected from the lethal effects of future stream flows. On rivers in arid and semi-arid western North America, such safe sites are created by dynamic fluvial processes that vary depending on geomorphic context, i.e., river bend migration on meandering rivers with fine sediment, and channel narrowing on braided streams with course sediment loads. On braided rivers, such as the historic South Platte River, the process of channel narrowing depends upon the occurrence of one or more years of stream flows that are too low to re-work the channel bed sediments; this allows vegetation to establish on the formerly wide channel bed. Thus, on braided rivers, cottonwood establishment tends to be associated with periods of low flow (Johnson 1994). On rivers in the Great Plains, such narrowing typically occurs following flood-induced widening (e.g., on the Arikaree and South Fork Republican Rivers, Katz et al. 2005; and on Bijou and Kiowa Creeks, tributaries of the South Platte River, Friedman and Lee 2002), or following flow reductions downstream of dams (e.g., on the Arkansas River, Friedman et al. 1998).

The Historic South Platte River

Prior to the era of water development in the basin (circa 1880), the South Platte River experienced an annual hydrograph dominated by mountain snowmelt, with high flows typically occurring in May and June, and low flows occurring in late summer. Indeed, the lower reaches of the South Platte River were likely ephemeral, as the alluvial aquifer was too deep to maintain perennial flow (Dennehy et al. 1993). There was substantial inter-annual variability in flow, resulting from climate fluctuations. In addition, late summer thunderstorms occasionally produced large floods in tributaries that may have affected flow in the mainstem (e.g., West Bijou and Kiowa Creeks, Friedman and Lee 2002).

East of the foothills, the South Platte River historically had a braided form, supporting a mosaic of riparian vegetation types but not a continuous forest. Braided rivers are naturally wide and shallow, with a coarse sediment load; stream flow is distributed among multiple, shifting channels separated by transient sand or cobble bars within the active channel zone. The historic South Platte River was approximately 500 to 800 m wide, with multiple channels and many sand bars comprising the active channel zone (Nadler and Schumm 1981). The extent of forest vegetation in the active channel zone was limited by the combination of high spring flows that reworked channel bed sediments and eroded seedlings, and low late summer flows that created drought conditions. Thus, pre-development riparian vegetation was characterized by a mosaic of grasslands, marshes, and isolated woodland patches (Nadler and Schumm 1981, Johnson 1994, Wohl 2013). Today's continuous gallery forest did not exist 150 years ago.

Changes to River Hydrology, Channel Form and Riparian Vegetation

The South Platte River today differs significantly from historic conditions, in terms of hydrology, fluvial geomorphology, and vegetation (Nadler and Schumm 1981, Johnson 1994, Strange, Fausch, and Covich 1999, Waskom 2013, Wohl 2013). Water development in the South Platte Basin began in the 1840s, with the construction of canals to support irrigated hayfields, and eventually crops such as alfalfa, potatoes and sugar beets. The system now includes more than 18,500 diversion points, as well as many off channel reservoirs. Importantly, the South Platte River also receives considerable water inputs from trans-basin diversions, totaling approximately 0.49 km^3 (400,000 acre-feet) per year, primarily from the Colorado River basin (Dennehy et al. 1993, Waskom 2013). In addition, non-tributary irrigation groundwater provides a considerable input to South Platte surface flow, totaling approximately 0.04 km^3 (30,000 acre-feet) per year (SPBRT/MBRT 2015). Return flows (comprised of surface water and groundwater) dominate the hydrology of the South Platte River basin, and most streamflow is used several times as it makes its way downstream. Native surface flow equals roughly 1.73 km^3 (1.4 million acre-feet) per year, while return flows and subsequent water re-use allow for annual diversions of approximately 4.93 km^3 (4.0 million acre-feet, SPBRT/MBRT 2015). In sum, key effects of water management have been the stabilization of South Platte River streamflow (i.e., reduced seasonal flow variation), enhanced annual flow volume, and augmentation of the alluvial aquifer by seepage from the vast network of irrigation ditches, canals and reservoirs (Waskom 2013). Thus, the river now has perennial streamflow along its entire length, supported by a shallow alluvial aquifer.

The present-day broad, spatially continuous cottonwood forest on the South Platte River in eastern Colorado became established between 1900 and 1930, as the wide river channel became narrower in concert with anthropogenic hydrologic alterations (Nadler and Schumm 1981, Johnson 1994, Wohl 2013). These hydrologic changes, coupled with occasional droughts, allowed recruitment of cottonwoods and willows on the former braided channel bed. According to one study, by 1937 approximately 90% of the formerly active channel area on the South Platte River in eastern Colorado was vegetated (Johnson 1994). This vegetation, in turn, stabilized channel morphology and further promoted the narrowing of the river to its present more stable, sinuous form with fewer channel threads. Thus, most cottonwoods on the South Platte River date to this episode of channel narrowing. For example, 43% of cottonwoods trees at a study site in Logan County, Colorado became established between 1929 and 1949 (Sedgwick and Knopf 1989). Today, the main pulse of forest expansion appears to have ended as the area available for colonization has been reduced and a new equilibrium channel width has been attained (Johnson 1994).

The Future of the South Platte River Riparian Forest

The long-term persistence of a riparian cottonwood forest on the South Platte River in northeastern Colorado depends on river-related geomorphic processes (i.e., sediment erosion and deposition) and hydrologic conditions (i.e., flow dynamism and groundwater levels) that support native trees. Because cottonwoods and willows are disturbance-dependent pioneer species, a steady state forest over the long term requires dynamic processes of flooding, erosion and sediment deposition to create suitable seedling establishment sites. These processes can be episodic, but must occur frequently enough to rejuvenate the forest as mature cottonwoods senesce and die, typically by 150 years of age. In the absence of sufficient levels of fluvial disturbance, forest succession would likely result in a shift in forest composition to a novel assemblage of non-pioneer species such as green ash (*Fraxinus pennsylvanica*), boxelder (*Acer negundo*), Siberian elm (*Ulmus pumila*), Russian olive (*Elaeagnus angustifolia*), and eastern juniper (*Juniperus virginiana*). Indeed, some authors have cautioned that this is the case, interpreting the twentieth century channel narrowing event as a discrete, historic occurrence that has ended (Sedgwick and Knopf 1989, Johnson 1994). According to this view, a new equilibrium channel width has been attained (Friedman et al. 1997), and ecological succession is now the dominant process operating in the riparian forest.

On the other hand, the South Platte River may still maintain enough hydrologic dynamism to enable continued cottonwood and willow recruitment, albeit in a smaller area than that covered by the historic narrowing episode (Friedman et al. 1997). Despite the intensive water development in the South Platte basin, there is still substantial flow variability, including inter-annual variations in flow volume and ecologically important large floods. Annual flow at Julesburg, Colorado ranged from 0.04 to 2.63 km^3 (30,355 to 2,130,245 acre-feet) between 1925 and 2012 (Waskom 2013). Large floods still occur in the river, e.g., in 1921, 1935, 1965, 1973 and 2013 (Figure 3). Thus, the South Platte River is a highly modified system that nonetheless experiences substantial hydrologic variability relevant to the structure and functioning of riparian ecosystems.

Consistent with this idea, GIS analysis of a series of historic aerial photographs suggests that at a decadal time scale cottonwood forest areal extent has

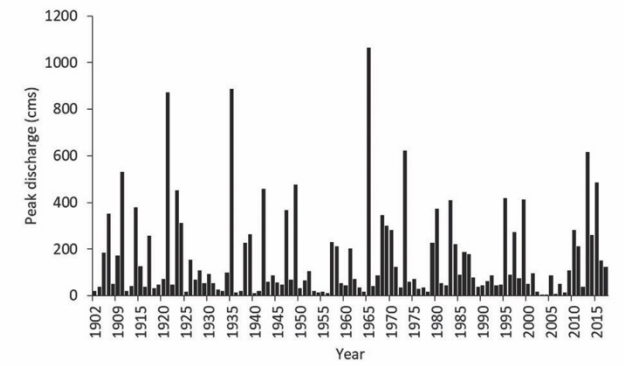

Figure 3. Instantaneous peak discharge for the South Platte River at Julesburg, Colorado (USGS gage #06764000).

fluctuated between approximately 19% and 26% of floodplain area since 1959 (Katz and Salo, unpublished data). These fluctuations appear to correspond with differing flow levels. For example, we recorded a 20% increase in forested area from 1998 to 2006, a time of low flow and drought conditions, and a 13% decrease in forested area between 2006 and 2015, a time period with two high flow events (Figure 3). Similarly, Snyder and Miller (1991) found a slight increase in river channel width and loss of cottonwood forest area on the South Platte River in eastern Colorado between 1941 and 1979, based on aerial photograph analysis. They were optimistic about cottonwood recruitment, suggesting that it still occurs under the present hydrologic regime. Here, forest loss results from the erosion and sediment deposition necessary to create suitable sites for cottonwood recruitment, potentially enabling regeneration of the riparian forest.

For the past 150 years, the water of the South Platte River has supported growing populations in northern Colorado. As such, the hydrology, and related fluvial and ecological systems of the South Platte River have been dominated by anthropogenic water management. At the same time, natural processes of high and low flow events continue to influence the river and its riparian forest. As Colorado seeks to meet the growing water demands in the South Platte River basin, understanding the long-term dynamics of the South Platte River riparian forest is critical to the management of this valuable natural resource.

References

Dennehy, K. F., D. W. Litke, C. M. Tate, and J. S. Heiny. 1993. South Platte River Basin—Colorado, Nebraska, Wyoming. *Water Resources*

Bulletin 29 (4):647-683. doi: 10.1111/j.1752-1688.1993.tb03231.x.

Friedman, J. M., M. L. Scott, and G. T. Auble. 1997. Water management and cottonwood forest dynamics along prairie streams. In *Ecology and conservation of Great Plains vertebrates*, ed. F. L. Knopf and F. B. Samson. New York: Springer-Verlag.

Friedman, J. M., W. R. Osterkamp, M. L. Scott, and G. T. Auble. 1998. Downstream effects of dams on channel geometry and bottomland vegetation: Regional patterns in the Great Plains. *Wetlands* 18:619-633. doi:10.1007/BF03161677.

Friedman, J.M. and V.J. Lee. 2002. Extreme floods, channel change, and riparian forests along ephemeral streams. *Ecological Monographs* 72, 409-425. doi:10.1890/0012-9615(2002)072[0409:EFCCAR]2.0.CO;2.

Johnson, W. C. 1994. Woodland expansion in the Platte River, Nebraska: Patterns and causes. *Ecological Monographs* 64:45-84. doi:10.2307/2937055.

Katz, G. L., J. M. Friedman, and S. W. Beatty. 2005. Delayed effects of flood control on a flood dependent riparian forest. *Ecological Applications* 15 (3):1019-1035. doi:10.1890/04-0076.

Nadler, C. T., and S. A. Schumm. 1981. Metamorphosis of South Platte and Arkansas Rivers, eastern Colorado. *Physical Geography* 2:95-115. doi:10.1080/02723646.1981.10642207.

Sedgwick, J., and F. L. Knopf. 1989. Demography, regeneration and future projections for a bottomland cottonwood community. In *Freshwater wetlands and wildlife: Proceedings of a symposium held at Charleston, South Carolina, March 24-27, 1986,* ed. R. R. Sharitz and J. W. Gibbons. DOE Symposium Series, No. 61. prepared by Office of Scientific and Technical Information.

Snyder, W., and G. Miller. 1991. Changes in plains cottonwoods along the Arkansas and South Platte Rivers—eastern Colorado. *Prairie Naturalist* 23:165-176.

[SPBRT/MBRT] South Platte Basin Roundtable/ Metro Basin Roundtable. 2015. South Platte Basin Implementation Plan. https://www.colorado.gov/pacific/sites/default/files/SouthPlatteBasinImplementationPlan-04172015.pdf.

Strange, E., K. Fausch, and A. Covich. 1999. Sustaining ecosystem services in human-dominated watersheds: Biohydrology and ecosystem processes in the South Platte River Basin. *Environmental Management* 24:39-54.

Waskom, R. 2013. Report to the Colorado Legislature Concerning: HB12-1278 Study of the South Platte River Alluvial Aquifer. http://www.cwi.colostate.edu/southplatte/files/report/HB1278%20Final%20Report.pdf.

Wohl, E. 2013. *Wide Rivers Crossed: The South Platte and the Illinois of the American Prairie*. Boulder, CO: University Press of Colorado.

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CULTURAL LANDSCAPES OF THE ROCKY MOUNTAIN WEST

St. Catherine of Siena Chapel, Allenspark, Colorado. Photo by Mike Goad.

PIKES PEAK: CREATING A SENSE OF PLACE FOR COLORADO SPRINGS

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General William Jackson Palmer, a Civil War veteran from Philadelphia who worked after the war as Secretary and Treasurer for the Kansas Pacific Railroad, first came through the Pikes Peak region in 1868 while surveying possible rail corridors. Palmer left the Kansas Pacific to build his vision for a railroad that would run north-south and connect the interior United States to Mexico. The Denver & Rio Grande (D&RG) Railroad was organized in autumn 1870. To run his new company, Palmer devised a plan for a new town, one not based on the norms of mining, farming or other resource exploitation so common in the West. His dream was for a resort, a getaway for eastern friends and investors—a place of refined culture in which to relax amidst the natural splendor of the Rocky Mountains. Palmer sought east coast investors to create a land company, expecting to sell lots, create a model town, and get rich in the process.

Where to locate his new town? No better place could be found than the contact point between plains and mountains, and no more abrupt transition existed than where Pikes Peak jutted up from the piedmont. Pikes Peak is a lone sentinel, an isolated "fourteener" farther east than the other 52 mountains over 14,000 feet in Colorado, and standing above the plains as a clear marker for this new physiographic province, the Rocky Mountains. Named after explorer Zebulon Pike who led an expedition seeking the headwaters of the Arkansas River in 1806, its proximity to the Colorado Front Range provides immediate access to this mountain wonderland. Pikes Peak is the reason for the location of Colorado Springs. As described by author Helen Hunt Jackson, Colorado Springs would be a town "lying due east of the Great Mountains and west of the sun" (Jackson 1898, 225). Palmer himself described the sensation one feels, after the arduous travel across the Great Plains, of reaching the base of the Rocky Mountains: "It is as though one had crossed the sea and reached the shores of a new country, full of novel attractions and advantages" (Palmer 2009 [1874], 143).

Surveys were made, stakes were driven, and the city was founded on July 31, 1871 (Figure 1). For his dream city to come true, he and others immediately recognized the need for a steady supply of water, the resource most lacking in his little utopian village. With only two small streams and no natural lakes, Colorado Springs is one of the few western cities not located adjacent to a reliable water source. Generating a sufficient supply of water would preoccupy city leaders from the first years up to the present day. The initial source of that water, of course, could only be the adjacent mountain, an "island of moisture" that characterizes the Rocky Mountain West (Vale 1995), from which all streams emerged. City leaders wasted little time exploiting this local resource.

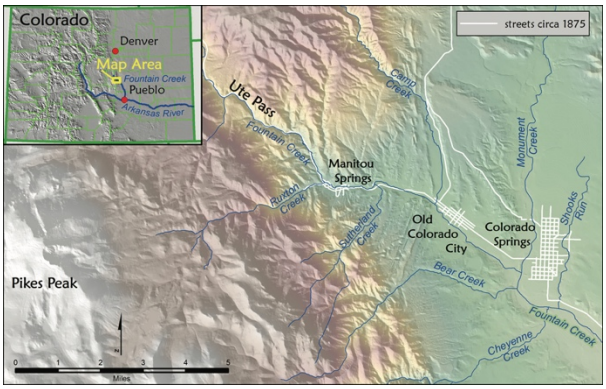

Figure 1. Colorado Springs, at the base of Pikes Peak where Fountain and Monument creeks join. The tiny settlement at Old Colorado City predated Colorado Springs, and Manitou Springs was built around mineral pools at the entrance to Ute Pass.

The Mountain Environment

General Palmer and a committee of investors who founded the city immediately built a canal that tapped Fountain Creek to irrigate lots, with water flowing by November 1871. To provide more reliable and clean water, in 1879 the city tapped Ruxton Creek, a tributary to Fountain Creek, which ran through Manitou Springs, the small settlement adjacent to Colorado Springs. The first pipe from the Ruxton water intake to a storage reservoir was completed in 1880, and

from there water lines ran into town to serve residents (Colorado Springs Utilities 2010). Colorado Springs leaders quickly recognized the need to scale up their water delivery infrastructure. From 1890 until 1929 the city further exploited resources on the south slope of the mountain, following Ruxton Creek up to its headwaters and, importantly, over a divide and into the adjacent watershed of Beaver Creek that did not even flow to Colorado Springs. Diverting water across watersheds represented a quantum leap in the development of water resources. No longer were people constrained to water flowing within their own basin; now water from anywhere was conceptually open for the taking. Tapping into Beaver Creek and diverting that water down Ruxton Creek was not the state's first out-of-basin transfer, but it was one of unprecedented scope, an ambitious process of turning water out of its natural watershed and importing it to areas of demand (Poulton 1989). The city's actions contributed towards the legal framework for water in the West known as the doctrine of prior appropriation, commonly called "first in time, first in right." This new legal framework for water rights evolved throughout the Rocky Mountain West as new settlers fought over the region's limited access to water (Worster 1986; Limerick and Hanson 2012).

Colorado Springs next began building the North Slope system in 1933 to bring more water into its distribution system. The first north slope diversion of water began in 1934, with two reservoirs completed by 1937. By later purchasing several smaller water companies on the north and south ends of the city, Colorado Springs fully exploited runoff from Pikes Peak. These resources were sufficient until the booming post World War II growth, when Colorado Springs began a series of projects to tap water from across the continental divide and pump well over 100,000 acre-feet annually to the city from hundreds of miles distant. Despite these modern feats, Pikes Peak water sustained the city nearly a century and continues to connect residents with its mountain environment.

While the city went to great efforts to manipulate the environment to deliver water, its climate was an environmental attribute that required no human engineering. Dry air, sunny days, and high altitude are physical dimensions of Colorado Springs that were marketed and exploited, particularly for those seeking relief from the most dreaded disease, tuberculosis. Tuberculosis (TB) has plagued humanity since before recorded history, and until the mid-1940s, there was no known cure. By the late nineteenth century, the best option for TB sufferers was to relocate to a place with more favorable climatic conditions. Colorado Springs became a preferred destination for those chasing the cure, and caring for those health seekers was the first growth industry of the city. The high, dry air of the Pikes Peak region, with abundant sunshine, positioned the city to develop a robust health economy. Building upon early resorts at nearby Manitou Springs mineral pools and adopting the successful model of health spas first developed in Germany and Switzerland, a dozen sanatoria located in Colorado Springs as the city actively promoted its curative properties that could be found from its mountain air, scenery, and sunshine.

The Mountain Rock

As its health resort reputation was growing, Colorado Springs residents tapped into the geologic structure of Pikes Peak to generate its biggest boom—gold in Cripple Creek on the west side of the mountain. This mining boom began in the 1890s and led Cripple Creek to become the largest gold district in the country, with capital investment and ownership controlled by Colorado Springs business leaders. This industrial success, as well as prolonged labor conflicts at the mines, initiated a pro-business, anti-regulatory, free market-oriented political culture that persists in Colorado Spring to this day (Suggs 1972).

The wealth generated from Cripple Creek fundamentally changed the built environment of Colorado Springs. A level of opulence shaped the architecture of civic and private buildings downtown, new posh hotels, and of houses in the nearby neighborhoods. The economic activity drove new jobs as investors congregated in Colorado Springs to reap the rewards of the gold bonanza. Cripple Creek also initiated an industrial transition for Colorado Springs. Because of the low-grade gold ore in the district, heavy industrial processing was crucial to extract gold. Colorado Springs capitalists who owned mines in Cripple Creek sought to vertically integrate production, building four large smelters on the west side of Colorado Springs, with two direct rail lines taking supplies and people up the mountain and bringing ore down. Spencer Penrose and partners built both the Colorado-Philadelphia in 1896 and the Standard mill in 1901, James Burns linked his Portland mine to the new Portland mill in 1901, and the Golden Cycle became the largest smelter in 1906, owned by John Milliken who also owned the Golden Cycle mine. The

west side of the city evolved into the working-class neighborhood that fostered a raucous reputation for bars and bordellos, with a large immigrant labor pool of Italians, eastern Europeans, and New Mexico Hispanos.

During the Cold War, there was another attribute that the solid granite of Pikes Peak could offer: security. Colorado Springs actively recruited and grew a military economy with the construction of Fort Carson in 1942, then enhanced that reputation once the Air Force was founded as a new branch of the armed forces in 1947. In addition to three Air Force bases located in the city, the crown jewel was locating the U.S. Air Force Academy on the north side of the city in 1954. Its modernist architecture, focused on the cadet chapel, offers an enduring landmark for the city. But from a strategic purpose, the Pikes Peak massif—specifically Cheyenne Mountain on its steep southeastern edge—provided a seemingly impenetrable fortress to locate the North American Aerospace Defense Command (NORAD). The Department of Defense devised an audacious plan to create the ultimate installation to monitor air defense that would continue running in the event of an attack. Construction began in 1961 on NORAD's Combat Operations Center inside of 9,500-foot-tall Cheyenne Mountain. Three miles of tunnels were blasted into the solid granite eastern-facing walls, removing over 700,000 tons of rock. Behind two 3-foot thick, 23-ton steel blast doors, the nerve center of the continent's defense against enemy attack would be 15 steel buildings, three story tall, comprised of more than 7,000 tons of steel plates, all sitting atop more than 1,319 steel springs that act like shock absorbers. It included a hospital, a six-million-gallon water reservoir, and a 10-megawatt power plant with 500,000 gallons of diesel fuel to keep the generators running for thirty days (Herst 1963).

"America's Atomic Mountain" was fully operational by April 1966. At the time, it was virtually indestructible (United States Air Force, n.d.). Using satellites, radars, and other sensors, information from all over the world was brought together at Cheyenne Mountain's Space Defense Operations Center to enable the resident four-star general to advise the president in case of an attack. Despite the design for maximum protection, the indestructability did not last long, as the Soviet Union increasingly built more powerful atomic bombs, with greater accuracy to target them. Soon it was recognized that a direct hit would destroy the entire mountain, facility and all. The encompassing mountain provided a symbolic feeling of safety, and certainly looked secure, but over time came to serve no real protective role. Despite its obsolete status, the Cheyenne Mountain facility boosted the city's reputation as the military Space Capital and enhanced its intimate connections with Pikes Peak.

The Mountain Playground

While the city has seen the waxing and waning of economic activities that shaped the landscape, tourism has been one influential sector that began with its founding and continues to this day. People have long been attracted to the Pikes Peak region for enlightenment, pleasure, entertainment, and recreation.

Initial wealthy Victorian travelers spent their days on the verandas, carriage paths, pavilions and ballrooms of Manitou Springs resort hotels—enclaves of comfort and sophistication, sheltered from the harshness of the elements (Philpott 2013). Such places provided an exposure to mystical wildness and danger, yet all within the confines of civilization. Vacationers came for therapeutic treatment in the Manitou mineral baths, but over time they were increasingly drawn by the easy access to hikes, rides, or excursions to nearby scenic spots (Hyde 1990; Limerick 2001; Philpott 2013). Tourism became attuned to active personal recreation. Horseback and burro adventures traversed trails on Pikes Peak and the foothills. Rainbow Falls and Williams Canyon (the "Baby Grand Canyon of Colorado"), both directly accessible from Manitou Springs, were favorite excursions, especially with a stop at the cliff dwellings, a reconstruction of Ancestral Puebloan ruins relocated from southwestern Colorado to a cave above town in 1906. At the top of Williams Canyon, the Cave of the Winds became a popular destination when opened to visitors in 1885 and continues as a tourist adventure to this day. Of course, tours to the Garden of the Gods and neighboring canyons and waterfalls were regular outings on the tourist circuit.

Railroads engaged the tourism business as well. Local entrepreneurs constructed the Cog Railway, with the first passenger train running to the summit of Pikes Peak on June 30, 1891 (Davis-Witherow 2007) (Figure 2). The local newspaper called the new train "the greatest achievement of the ages" (*Colorado Springs Gazette* 1891, 4). The southern rail line to Cripple Creek also advertised its spectacular scenery

Figure 2. Promotional brochure for the Cog Railway up Pikes Peak, circa 1920 (Colorado Springs Pioneers Museum).

"that bankrupts the English language," and the northern line ran popular wildflower excursions up Ute Pass to mountain meadows (CSCCRR 1915).

Colorado Springs gained the reputation as the oldest and most socially-exclusive western resort. The downtown Antlers Hotel, completed and opened on June 1, 1883, was strategically located due east, and up the small hill, from the D&RG station, so visitors arriving in town walked from the depot, across Antlers Park, and up a grand staircase to the impressive hotel foyer. Replete with turrets and bay windows in Queen Anne architecture, the 75-room hotel quickly gained the reputation as one of the best in the west and served to solidify the resort aura of the city (Feitz 1972). The original Antlers Hotel burnt down on October 1, 1898, from a fire in the railyard freight cars. The second Antlers was completed with a new Italianate style building on July 2, 1901. The hotel and mountain imagery became a key marketing symbol (Figure 3).

Figure 3. Postcard of the second Antlers Hotel, with an exaggerated Pikes Peak creating a dramatic backdrop, circa 1935 (Colorado Springs Pioneers Museum).

Spencer Penrose, scion of a wealthy Philadelphia family, struck it rich in Cripple Creek and used his wealth to build the Broadmoor Resort, which remains as one of the city's key attractions. Penrose became the king of regional tourist activities. He was fascinated with the invention of automobiles and saw the opportunity for auto-related tourism. In 1912 he started one of many auto-tour companies competing for tourist dollars, then created the Pikes Peak Auto Highway Company in 1913 and leased the old wagon road up the mountain from the Department of Agriculture. He opened the Pikes Peak Highway in 1916 with the first of what would become the annual Pikes Peak International Hillclimb (Lohse 2017). This race captured the imagination of the nation, and the "Race to the Clouds" remains the second oldest auto race in the country, after the Indianapolis 500. This event served to promote auto excursions throughout the region that proved a powerful

attractor, generating revenue from the many tourists who paid the toll to drive up Pikes Peak.

Pike National Forest borders the city's entire western edge. Protected public land since 1905, the forest offers a wealth of recreational opportunities. Local entrepreneurs started commercial ski sites as early as 1924, with seven different operations running at various times until 1991. Numerous reservoirs built by Colorado Springs Utilities attract regional anglers, and the trail network for hiking, mountain biking, and equestrian activities provides a playground for all levels of enthusiasts. Events such as the Pikes Peak Marathon, a grueling ascent and descent of Pikes Peak, and the increasingly recognized mountain bike opportunities put the city on the map with outdoor activity enthusiasts and organizations. The legacy of recreational tourism today pays increasing dividends, with over $2 billion spent annually on outdoor recreational activities in the Pikes Peak Region (Outdoor Industry Association 2018).

In addition to the powerful recreation economy, Colorado Springs is banking on the related sports economy as both a basic industry and a tourist attractor. Building upon an earlier focus on amateur sports at the Broadmoor, local leaders convinced the U.S. Olympic Committee, fiscally strapped and cramped in its New York City headquarters, to relocate to Colorado Springs in 1977. Enticed by generous incentives plus the 6,000 foot elevation beneficial to athletic endurance, the committee converted a 36-acre one time tuberculosis sanatorium and Air Force Base into the Olympic Training Center (OTC) in 1978, a complex with residence halls, gyms, rinks, pools, tracks, and other sporting facilities. Today about 15,000 athletes live for short durations each year at the OTC, with facilities such as the Velodrome bike track hosting regional competitions. This has spawned a host of related businesses—59 national and international sports organizations, plus 23 national governing bodies for Olympic sports—that generate an agglomeration economy around amateur sports.

Not only does the city host the flagship Olympic Training Center, it is the sole host for the U.S. Olympic & Paralympic Committee (USOPC) Headquarters. When the USOPC considered relocating in 2008 after it outgrew its facilities, the city gambled on the cultural and economic capital it could exploit by subsidizing the USOPC, offering $53 million in taxpayer money for a new downtown location, upgrades to the OTC, and other site improvements to entice the organization to stay. In exchange, the USOPC agreed to stay for 25 years, and more importantly, allowed Colorado Springs exclusive marketing as "Olympic City USA," the city's new brand complete with a logo blending the Olympic colors with a stylized Pikes Peak (Figure 4). The mountain representation used in the city's logo shows that Pikes Peak is a symbolic landscape, one that reflects the importance of the human-nature connections driving the city's sense of place (Blake 1999). The expected completion of the new Olympic Museum in 2020 further enriches the Olympic City image and place identity.

Figure 4. The Olympic rings are adapted to form slope faces of Pikes Peak in the city's new Olympic City USA logo adopted in 2018.

The Mountain Identity

Colorado Springs from its very founding charted a path different from most western cities, banking on recreational pleasure seekers and the beauty of its environment. It has successfully marketed its landscape to create its sense of place before this became a standard strategy among the many western amenity-based towns of today. Colorado Springs is a city of the Rocky Mountain West, and ever present is Pikes Peak, a "peak of identity" that defines the Colorado Springs region (Blake 2002) (Figure 5). The mountain is the reason for the city's location. Few other cities have a natural landscape that rises more than 8,000 feet in vertical relief in just 10 horizontal miles, a feat that a 1980s-era tourism map described as, "A Metropolis at the foot of a Majesty." The mountain is the source for much of its water; the snow cap not only an inspiration to look at but a reminder of the fragility of our environment. The mountain shapes the weather, as each summer day starts with brilliant blue skies, slowly clouds build up from the rising air currents, then thunderstorms break free from the

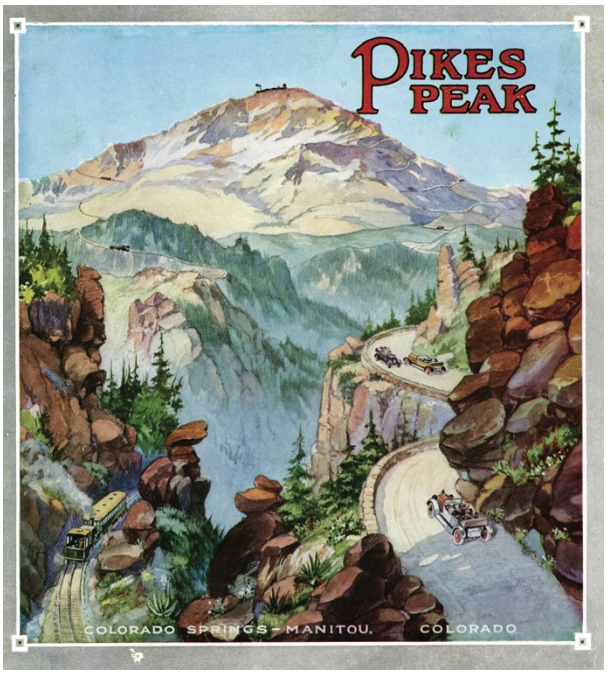

Figure 5. Pikes Peak is the dominant icon marketed by the recreation and tourism industries so successfully that the mountain and city are inseparable, circa 1935 (Colorado Springs Pioneers Museum).

bonds of the slope and roll past the city on their way to Kansas. On its slopes people ride bikes, ski, and hike, and in its streams and reservoirs they fish. They walk, drive, or take the cog railroad to its summit, and gold is still extracted from its western slopes. Outdoor enthusiasts relish in nature to refresh themselves, recreationists relax in the pines. Marketers promote its beauty and therapeutic effects, while military recruits and Olympic athletes train in the high altitude. "America's Mountain" remains a very symbol of liberty. It is the western frame of view that all residents look at each day, a point of reference and familiarity that signifies home. Pikes Peak is inseparable from Colorado Springs: the mountain creates the city's sense of place.

References

Blake, K. S. 2002. Colorado fourteeners and the nature of place identity. *Geographical Review* 92 (2):155-179.

———. 1999. Peaks of identity in Colorado's San Juan Mountains. *Journal of Cultural Geography* 18 (2):29-55.

Colorado Springs and Cripple Creek Railroad (CSCCRR). 1915. "Through the Heart of the Rockies into the Land of Gold." Promotional brochure, accessed at the Starsmore Center for Local History, Colorado Springs Pioneers Museum.

Colorado Springs Gazette, July 4, 1891, p. 4.

Colorado Springs Utilities. 2010. "Water Historic Timeline." Unpublished document, accessed at the Starsmore Center for Local History, Colorado Springs Pioneers Museum.

Davis-Witherow, L. 2007. Marketing the mountain: Pikes Peak in the popular imagination. In *To Spare No Pains: Zebulon Montgomery Pike and His 1806-1807 Southwest Expedition*, ed. T. Blevins, M. Mayberry, C. Nicholl, C.P. Otto, and N. Thaler, 217-238. Colorado Springs: Pikes Peak Library District.

Feitz, L. 1972. *The Antlers: A quick history of Colorado Springs' historic hotel*. Denver: Golden Bell Press.

Herst, R. 1963. Steel city being built under Cheyenne Mountain. *Colorado Springs Gazette Telegraph*, December 5, p. 43.

Hyde, A. F. 1990. *An American vision: Far western landscape and national culture, 1820-1920*. New York: New York University Press.

Jackson, H. H. 1898. *Bits of travel at home*. Boston: Roberts Brothers, p. 225.

Limerick, P. N. 2001. Seeing and being seen: Tourism in the American West. In *Seeing and being seen: Tourism in the American West*, ed. D. Wrobel and P. Long, 39-58. Lawrence, KS: University Press of Kansas.

Limerick P. N., with J. L. Hanson. 2012. *A ditch in time: The city, the West, and water*. Golden, CO: Fulcrum.

Lohse, J. B. 2017. The Penrose Legacy: Ventures, vogue, & vagary. In *Bigwigs & benefactors of the Pikes Peak Region*, ed. H. Jordan, T. Blevins, D. Daily, S. Dean, C. Nicholl, and M. Olsen, 127-171. Colorado Springs: Pikes Peak Library District.

Outdoor Industry Association. 2018. *Technical Report*. Boulder, CO. Available at http://outdoorindustry.org.

Palmer, W. J. 2009 [1874]. The West-ward march of emigration in the United States, considering in its bearing upon the near future of Colorado & New Mexico. In *Legends, labors & loves of William Jackson Palmer*, ed. T. Blevins, D. Daily, C. Nicholl, C.P. Otto, and K. S. Sturdevant, 137-

182. Colorado Springs: Pikes Peak Library District.

Philpott, W. 2013. *Vacationland: Tourism and environment in the Colorado High Country.* Seattle: University of Washington Press.

Poulton, C. A. 1989. *A Historical geographic approach to the study of the institutionalization of the Doctrine of Prior Appropriation: The emergence of appropriative water rights in Colorado Springs, Colorado*. PhD diss., University of Minnesota.

Suggs, G. G. 1972. *Colorado's war on militant unionism*: *James H. Peabody and the Western Federation of Miners*. Detroit: Wayne State University Press.

United States Air Force. n.d. *The Cheyenne Mountain Story*. Promotional booklet, accessed at the Starsmore Center for Local History, Colorado Springs Pioneers Museum.

Vale, T. R. 1995. Mountains and moisture in the West, In *The mountainous West: Explorations in historical geography,* ed. W. Wyckoff and L. M. Dilsaver, 141-165. Lincoln, NE: University of Nebraska Press.

Worster, D. 1986. *Rivers of empire: Water, aridity, and the growth of the American West.* New York: Pantheon Books.

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THE COLORADO CRAFT BREWERY EXPERIENCE: HOW GROWTH IS RESHAPING ITS INDUSTRY

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In 2005, over 5,000 geographers gathered in Denver to attend the annual AAG meeting and explore the Mile High city and its surroundings. One of the many attractions in the region gaining attention was craft beer and visiting the places that make the beer firsthand. Although the industry was much smaller then, Colorado was already being recognized as a pioneer, with regional breweries like New Belgium starting to distribute outside of the state with their popular Fat Tire brand. More breweries like Avery, Breckenridge, Great Divide, Odell, and Oskar Blues were gaining renowned reputations with visitors from around the country. Brewpubs like Wynkoop, Rock Bottom, and Mountain Sun were combining original beer with creative cuisine. And a small homebrew shop in suburban Aurora started to sell its own beer directly to customers on site, making Dry Dock an early adopter of the taproom-only brewing model (Frank 2019). Visitors were coming to enjoy what Coloradans had been experiencing for years; remarkable craft beer and the spaces that create it. Today, the industry is larger than ever and its impacts on the state's economy and tourism are wide. Those who seek a craft brewery experience can now choose from over 400 unique locations and tap lists, whether concentrated in cities along the Front Range or spread out across smaller communities throughout the state. This paper will explore some of the spatial and temporal patterns associated with craft brewing sites in Colorado over the past four decades, focusing on regional trends within the state. To see how the craft beer scene has changed since that last meeting in Denver, brewery distributions in 2005 and 2019 are explored using descriptive measures of distance and density to highlight the changing industry.

Craft Beer and Colorado

The term "craft beer" has been applied to beer made by relatively small, traditional, and independent commercial brewers (Oliver 2011, Brewers Association 2019). The idea of characterizing beer as "craft" stems largely from a desire to distinguish mass-produced macro-beer made at large-scale breweries from those with smaller production; whether a brew-pub, microbrewery, or taproom. As small breweries have grown in size, distribution, and ingredients used, the definition has evolved to incorporate the ever-changing landscape, allowing these breweries to remain separate from macro classification (Watson 2018). This separation of scale, which shapes the trends, styles, and how people engage with craft beer has largely become its identity. In Colorado, residents embraced craft beer early on and continue to show overwhelming support for the industry as it grows and evolves.

Colorado's expansion of craft breweries mirrors a bigger nationwide trend, with much of the momentum starting in Western states like Colorado (McLaughlin, Reid, and Moore 2014). As of 2018, Colorado had the second most breweries (396) of any state behind California. It had the 4th most breweries per capita (9.2 per 100,000 21+ population), and the highest brewery per capita of any state with a population greater than 5 million. Colorado also had the highest economic impact per capita ($780) of any state (Brewers Association 2019). Table 1 shows Colorado's state ranking among six important economic factors related to the beer industry. No other state ranks in the top six of each of these categories. By 2018, 5.4% of all breweries in the U.S. (396 of 7,346) were in Colorado, a state with less than two percent of the U.S. population.

Tourism is a strong contributor to Colorado's craft beer identity. People who seek some of Colorado's unique outdoor recreational activities often do so in tandem with craft beer (Shilton 2019, Sealover 2016). Visiting a brewery after a long day hiking, biking, or skiing can provide a well-deserved reward. Some visitors come to Colorado just for the beer. Each fall, thousands of beer drinkers and brewers assemble in Denver for the Great American Beer Festival (GABF). This Colorado tradition has grown annually from humble beginnings of just two dozen breweries and 800 patrons in 1982 to nearly

Table 1. Leading State Craft Beer Sales and Production, 2018.

Rank	Craft Breweries	Breweries per Capita (21+ per 100,000)	Economic Impact (millions)	Impact per Capita (21+ per 100,000)	Barrels Produced per Year	Gallons per 21+ Adult
1	California (841)	Vermont (13.5)	California ($9,014)	**Colorado ($780)**	Pennsylvania (3,719,475)	Vermont (21.3)
2	**Colorado (396)**	Montana (11.4)	Pennsylvania ($6,335)	Vermont ($756)	California (3,421,295)	Delaware (12.5)
3	Washington (394)	Maine (11.3)	Texas ($5,077)	Oregon ($674)	**Colorado (1,522,834)**	Alaska (12.1)
4	New York (386)	**Colorado (9.2)**	New York ($4,126)	Pennsylvania ($657)	Ohio (1,398,358)	Pennsylvania (11.7)
5	Michigan (357)	Oregon (8.8)	Florida ($3,625)	Maine ($631)	Florida (1,373,558)	**Colorado (11)**
6	Pennsylvania (354)	Alaska (7.8)	**Colorado ($3,285)**	Montana ($626)	New York (1,270,157)	Maine (10.5)

Source: Brewers Association (2019).

700 breweries and over 60,000 patrons in 2019 (Acitelli 2013, GABF 2019). Nearly 800 medals have been won by Colorado breweries in the history of the event. GABF is just one of dozens of diverse beer festivals held annually in Colorado, drawing visitors from around the world. The state is also an important information hub for the beer industry. The Brewers Association (BA) and American Homebrewers Association (AHA) are headquartered in Boulder. BA is a non-profit organization, now behind GABF, that serves an important role promoting craft beer independence while protecting the interests of American craft brewers (Brewers Association 2019). The Colorado Brewer's Guild was established in 1995 by local brewers to build recognition and serve as a voice for the burgeoning community (Colorado Brewers Guild 2019).

Geography's Role in Craft Beer

Often those who seek and drink craft beer do so for more than just taste. They want to be part of a community that highlights quality over quantity. They seek a flavorful experience that goes beyond what is mass-produced; something that is local and unique, not ubiquitous and generic. Geography is a major contributing factor to that experience. Craft breweries everywhere have traditionally incorporated local culture in their identity and local imagery in their labels (Fletchell 2016, Quintana 2016, Schnell and Reese 2014, Schnell and Reese 2003). They create a sense of place that can be felt and consumed. In the early days, mountain imagery and outdoor activities were frequently represented on labels to market the Colorado lifestyle; as an identity for local Coloradans, and as a window into that lifestyle for other states where the beer was distributed (Sullivan 2017). Several represent some of Colorado's landscapes in their names, such as Upslope, Great Divide, Elevation Beer, and Left Hand (the name of a nearby stream), to name a few. Today, with the prevalence of craft beer throughout the U.S., selling place is less prioritized in marketing and distribution. Recently, Colorado brewers like New Belgium changed their recognizable Fat Tire label to remove the natural outdoor setting behind its iconic bicycle, while Oskar Blues abandoned the mountain scenery on their "original craft beer in a can" brand, Dale's Pale Ale (Shikes 2020c, Burke 2019). Local identity and culture are now more often reflected in the spaces where craft beer is consumed. Craft breweries build spaces that incorporate local creativity and engage with the community. They create atmospheres ranging from upscale to family-friendly; from spacious to cozy; with themes focused on neighborhoods to those more international, seeking inspiration from European, Latinx, and Asian cultures. They repurpose unused space, from old gas stations and body shops to elementary schools and mercantiles. Visiting these breweries provides an opportunity to interact with the space where the beer is created, converse with the artisans that make it, or simply mingle with others who share an interest in the craft culture; bringing the concepts of space, place, and culture to the forefront of the consumer experience with beer. For some,

visiting every brewery in the state has become an ambitious goal (Shikes 2016). However, with more than 50 new breweries opening in Colorado each year over the past five years, in new and more dispersed communities throughout the state, visiting all locations has become an increasingly more difficult task, in spite of recent closures.

Active and Closed Breweries Since 1979

Figure 1 depicts all of the identified breweries in this study since 1979. Active breweries in 2019 are classified by the decade these sites opened. Closed breweries are those that have ceased production at a given location. Not all closures in this study reflect a brewery that has gone out of business. Breweries that stop production at their original facility and relocate have new closing and opening dates applied to these locations. Those that have rebranded or changed ownership with a new name also have new dates assigned. Brewery data were compiled from several online resources, including Brewers Association, Beer Advocate, BeerMe, Colorado Brewery List, and Rate Beer, to identify location, dates of operation, and brewery type for each site (Beer Advocate 2019, Beer Me 2019, Brewers Association 2019, Colorado Brewery List 2019, RateBeer 2019). The dataset was created given the best information available, acknowledging any omissions or misrepresentations as unintentional. County boundary and 21+ population data were acquired from the Colorado Department of Local Affairs (Colorado Department of Local Affairs 2019). Annual estimates are available for each county since 1990.

Colorado is divided into eight regions to highlight spatial and temporal patterns of brewery growth within the state. Denver and El Paso counties are isolated given their large population centers of Denver and Colorado Springs, which are distinct from their surrounding suburban and rural areas. Boulder, as well as Larimer and Weld counties in the Northern Colorado (NoCo) region, are also isolated given their unique contributions in developing breweries. The remaining regions are directionally categorized. The Central region comprises of counties immediately surrounding Denver. The South region includes Pueblo and counties to the south. The West region contains mountain counties to the western border, including most major ski resort and popular outdoor recreation destinations. The East region consists of mostly rural counties on the Eastern Plains.

Spatial and Temporal Trend of Breweries

In the late 1970s, Coors, in Golden, was the only active brewery in the state and the last remaining to have survived Prohibition. In 1979, Boulder Beer opened on a goat farm near Boulder to become the state's first new brewery in over half a century (Boulder Beer 2019). More breweries would soon follow, thanks in part to a recent change in a federal law held over from Prohibition that had restricted brewing at home for personal consumption (Acitelli 2013, 57-59). The AHA was soon founded in Boulder and scores of new homebrewers would later become the craft brewers of future generations (Acitelli 2013, Sullivan 2017). Figure 3 shows a graph of the annual openings and closings of breweries throughout Colorado (top) and the total active breweries from 1979 to 2019 (bottom), categorized by region.

The first region that saw development was NoCo, home to the college town of Fort Collins and nearby Greeley. Five of the eight new breweries in the first decade opened here. The largest was "beer giant" Anheuser-Busch, which was joined by smaller, now-recognizable names like Odell and later New Belgium in 1991. Growth was slow at first, thanks in part to a sluggish Colorado economy and regulations preventing brewers from selling their beer on site (Sullivan 2017). However, by the late 1980s a change in the law made access easier. Denver got its first brewpub Wynkoop in 1988 becoming a model of brewing and urban renewal for others to soon follow. During the early and mid-1990s, the West region would see the most openings with mountain towns drawing skiing and outdoor enthusiasts to new breweries and brewpubs throughout that region. Boulder and NoCo would also gain large numbers of breweries relative to their small size, driven by access to nearby college-age consumers and significant technological and other professional services in the area, such as the emerging scientific and healthcare industries. By 1996, with statewide economic growth and subsequent opportunities for small businesses, the state had 64 openings with only three closings (Sullivan 2017).

By 1997, the trend slowed and breweries began to close. With market saturation and poorer-quality startups looking to cash in on industry success largely to blame, only the strongest would survive (Sullivan 1997). The total number remained somewhat stagnant throughout the early 2000s, with the exception of a growing number of brewpubs in Western mountain towns that continued to draw visitors from nearby

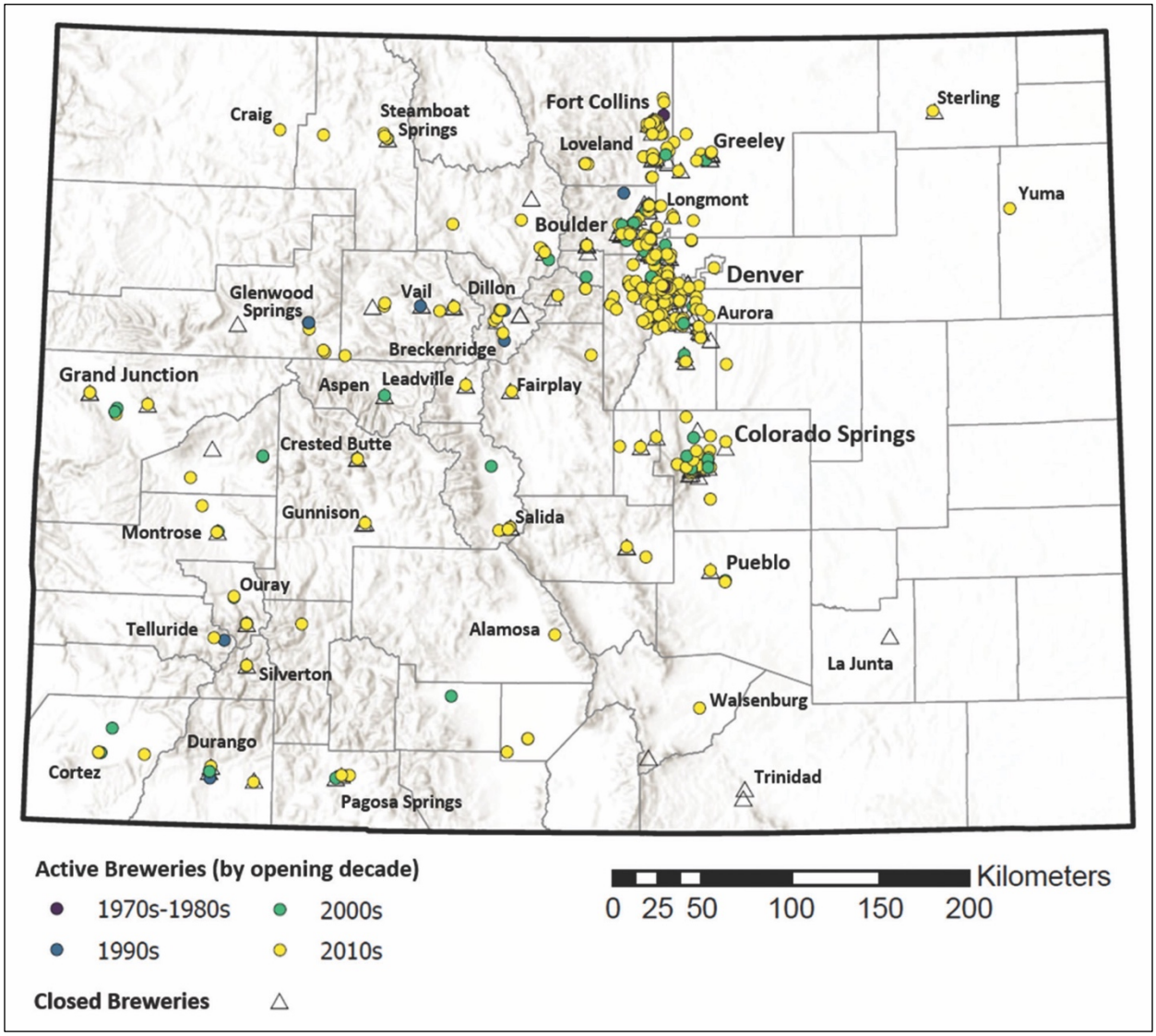

Figure 1. Active and Closed Breweries in Colorado, 2019. Data source: Brewers Association.

recreational activities. Despite limited growth in numbers, established breweries started building their production and distribution to reach audiences outside Colorado with their flagship beers and innovative releases, such as sours, imperials, and craft beer in a can (Shikes 2019a).

By 2010, another brewery boom would emerge, due largely to a change in the way breweries sold to customers. Taproom-only facilities were becoming more prevalent. Many breweries now sold most of their beer directly to customers on site without relying on distribution or the draw of food associated with brewpubs. Peaking in 2014, this boom saw tremendous expansion in Denver and the Central Region, as well as in Colorado Springs in El Paso County. Breweries were becoming centerpieces in urban revitalization by clustering within old industrial areas near downtown Denver, which was undergoing adaptive reuse. Despite controversies associated with gentrification, new condo developments were attracting young professionals, which in turn created demand for these watering holes. In the following years, the number of annual openings remained high, but closings started to once again increase. This time, with growing competition and limited profitability from trying to balance operational expenses and costly leases, new taprooms were struggling to a point of failure (Shumway 2018). Not all closures were

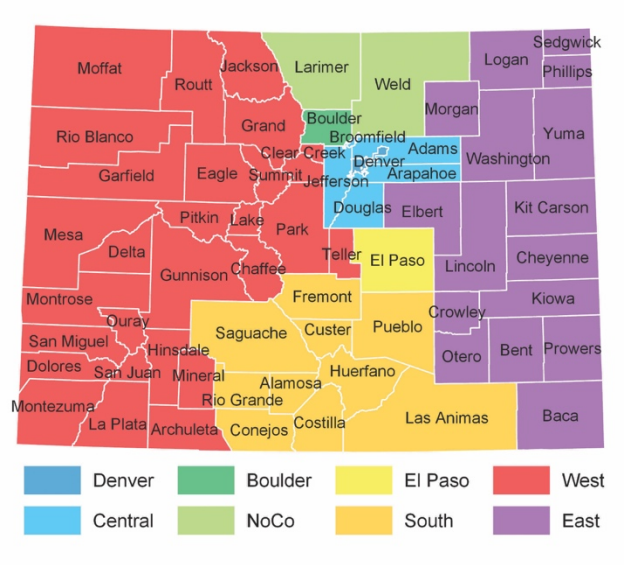

Figure 2. County and Regional map of Colorado.

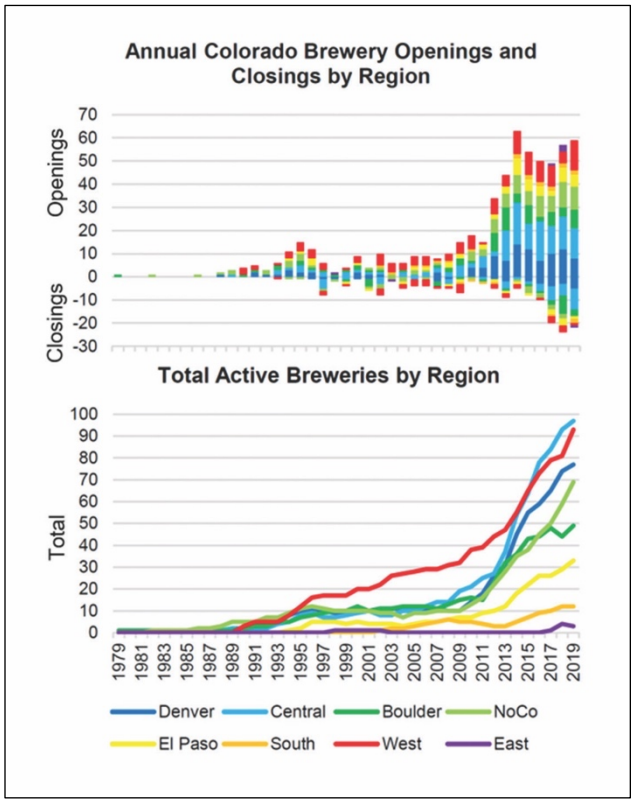

Figure 3. Annual Colorado Brewery Openings and Closings (top) and Total Active Breweries (bottom) by Regions identified in Figure 2.

financially driven, as some represented changes in ownership, with retiring brewers passing the torch to the next generation (Shikes 2018). Closures peaked in 2018 with 24 statewide, including eight in the Boulder region alone. Nearly as many sites have closed since 2014 as had in the previous 35 years. While the number of recent closings may yet signify a reversal of fortunes for the industry, the sizable number of openings each year had given Colorado its largest number of active breweries to date in 2019.

Then and Now: Comparing 2005 and 2019

To capture how the craft beer scene has evolved since the last AAG meeting in Denver, Table 2 compares Colorado's breweries in 2005 and 2019. Growth has been largely universal, with the total number of identified breweries in this study increasing nearly 500% from 77 in 2005 to 433 in 2019. Most of the eight regions had experienced demonstrable growth of at least 300%. In 2005, the West had the greatest representation with 36% of the state's breweries, more than twice any other individual region. By 2019, other regions saw a larger share, with the suburbs around Denver expanding their overall numbers to match the West with over 20% each. As the 21+ population grew by nearly one million, the total number of new breweries allowed the per capita growth of each region to increase dramatically. In 2019, Boulder had nearly 20 breweries per 100,000 21+ population com-pared to approximately 6 per 100,000 in 2005. As craft beer evolved, so did its demand.

New breweries tended to open near other existing sites, increasing their overall density. In 2019, 51.5% of all breweries were within 1km and 87.5% were within 5km of another site, up from 31.2% and 57.1% respectively in 2005. Denver currently has the largest concentration of breweries, clustered in a small area within the city. In 2019, at least three breweries in Denver's redeveloped River North Arts District near downtown had 15 other sites within 1km, many of which have opened in the last decade. Eight breweries in the city had 69 sites within 5km. This shows that breweries continued to cluster near other sites, which built a community and destination for beer tourism, even as the number of sites and competition increased. Several companies currently capitalize on these close proximities by offering bus tours between multiple breweries in cities like Denver, Longmont, and Fort Collins, among others. When looking at each

Table 2. Comparison of brewery spatial characteristics between 2005 and 2019.

Statistics	2005	2019
Total number of breweries (21+ population; breweries per 100,000 21+)	77 (3,292,354; 2.34)	433 (4,265,972; 10.15)
Denver	11 (417,419; 2.64)	77 (568,149; 13.55)
Central	10 (1,206,704; 0.83)	97 (1,599,768; 6.06)
Boulder	12 (201,927; 5.94)	49 (245,919; 19.93)
NoCo	9 (344,176; 2.61)	69 (498,378; 14.17)
El Paso	5 (388,827; 1.29)	33 (526,371; 6.39)
South	2 (193,858; 1.03)	12 (217,300; 5.56)
West	28 (425,844; 6.58)	93 (513,640; 18.11)
East	0 (113,599; 0.00)	3 (120,372; 2.52)
Density		
Breweries within 1km of another site	24 (31.2%)	223 (51.5%)
Breweries within 5km of another site	44 (57.1%)	379 (87.5%)
Most breweries within 1km	7 (at 4 sites in Denver)	15 (at 3 sites in Denver)
Most breweries within 5km	11 (at 2 sites in Denver)	69 (at 8 sites in Denver)
Distance		
Mean (Median) distance between nearest breweries (km)	12.9 (2.7)	3.4 (0.94)
Breweries more than 25km from nearest site	13 (16.9%)	14 (3.2%)
Breweries more than 50km from nearest site	4 (5.2%)	3 (0.6%)
Most isolated brewery community	Trinidad (122km)	Walsenburg (72km)
Counties without a brewery	40 of 64 (62.5%)	21 of 64 (32.8%)
Central	2 of 5 (40.0%)	0 of 5 (0.0%)
South	8 of 10 (72.2%)	4 of 10 (40.0%)
West	14 of 28 (50.0%)	4 of 28 (14.3%)
East	16 of 16 (100.0%)	13 of 16 (81.3%)
Most populated county (21+) without a brewery	Adams (364,781)	Morgan (19,807)

brewery's distance to its nearest neighbor, that gap has closed, with the mean and median distances dropping from 12.9km and 2.7km in 2005 to 3.4km and 0.94km in 2019. More than half of all breweries were now within one kilometer of their closest neighbor.

Fewer breweries were in isolation as well. Only 3.2% of Colorado's breweries were more than 25km and 0.6% were more than 50km from their nearest neighbor in 2019, down from 16.9% and 5.2%, respectively, in 2005. Walsenburg is currently the most isolated municipality with a brewery, located

72km from its nearest site in Pueblo. Isolated breweries in Trinidad near the state's southern border in 2005 have since closed.

The number of counties that are now home to breweries had increased, mostly within the West region. Only 32.8% of Colorado counties were still without a brewery in 2019 compared to 62.5% in 2005. The East continued to be underrepresented with the highest percentage of counties without a brewery at 81.3%, down from 100.0% in 2005. With few population centers and traditional brand loyalty to macrobrew in the East, only 3 isolated breweries currently exist. However, these recent additions might be evidence of change coming to that region. Populous counties like Adams in the Central region were better represented in 2019. Despite an estimated 21+ population of 364,781, there were no breweries in 2005. By 2019, it had 18 sites. The most populous county currently without a brewery is Morgan in the East with a 21+ population of 19,807.

Persistence has been a large part of Colorado's brewery success story. Many breweries from 2005 were still around in 2019, with 45 of Colorado's 77 (58%) breweries still active at the same location. And al-though 32 sites have closed, six have relocated and 21 have been replaced by active breweries at either the same location or within 1km of the former sites. Over 100 Colorado communities were represented by a brewery in 2019, up from 42 communities in 2005. Only four from 2005 were no longer represented in 2019 (Grand Lake, Gypsum, Keystone, and Trinidad).

Change in Colorado's Craft Beer Identity

As the overall numbers have increased and spread into new communities, the craft beer identity has evolved. What started out as a hobby to create alternatives to mass-produced light lagers became a rediscovery of beer styles largely forgotten after Prohibition, with the emergence of ales, such as stouts, porters, wheats, and India pale ales (IPAs) dominating brewery portfolios of the 1990s and early 2000s. Today, with increasing competition and maturing palates of their customers, breweries have worked hard to create a niche by offering new innovative styles, distinct themes, special one-time releases, unique spaces to visit, and even diversity in brewers and ownership. Hazy IPAs and pastry stouts have dominated some of the trends in recent years. But we have also seen a return to traditional lagers and a shift to gluten-free, low-alcohol, low-calorie options, such as session ales and seltzers to add to the existing variety of taps (Shikes 2020a). The evolution of style diversity can be captured by the number of different medals awarded at the GABF. In the late 1980s, there were fewer than 20 categories. By 2005, that number increased to 69. In 2019, there were 107 unique categories with several dedicated to just hazy beers alone (GABF 2019). Young, small independent breweries have also gained recognition. Thirty of Colorado's 33 medal-winning breweries at 2019's GABF have opened within just the past 10 years, including Brewery of the Year award winners Comrade in Denver and Westbound and Down in Idaho Springs from the West region (GABF 2019). Collaboration among breweries has also helped boost the industry and support the community they have created (Wolinski 2018, Mathias et al. 2015). Breweries work together to share ideas (and sometimes space), learn new techniques, and contribute exclusive one-off beers that go beyond flagship offerings.

Since the early 2000s, social media has changed the way people interact with breweries (Acitelli 2013). Websites like Beer Advocate and Untappd allow users to engage with the beer community using ratings and check-ins. Twitter, Facebook and Instagram allow breweries to have a direct connection with their customers by advertising special events and limited releases. Taprooms have also developed a symbiotic relationship with food trucks by providing similar dining options as a brewpub without the commitment of an onsite kitchen.

What's Next for Craft Breweries in Colorado?

Despite innovations, the trend of fewer openings and more closings has led to questions of sustainability and whether a saturation point has been reached (Shikes 2019b). Following years of expansion, popular beer cities around the U.S. like Denver, Seattle, Chicago and San Diego are now seeing a decrease in demand (Barton 2020). Some existing breweries struggle to survive as more attempt to join the crowded field. Denver, Boulder, and Central regions have seen the most closures in recent years. Lease terminations, financial hardships, quality control, and increased competition are just a few of the reasons explaining this recent downturn. Even Boulder Beer, Colorado's oldest craft, closed its brewpub in January 2020. Although their flagship beers will still be produced and distributed with the help of a local contract brewer, their Boulder space is gone (Shikes 2020b). Nearly 200 sites in the state

have closed, relocated or rebranded since 1979, with a mean operating age of 5.5 years. Despite that, more than 50 of these closed locations have found new breweries to replace them in the same space.

Many of the recognizable Colorado craft beer names of the past no longer uniquely belong to the state. Early on, several established breweries expanded their distribution to national recognition and popularity given some early prosperity. Both New Belgium and Oskar Blues opened up production facilities in the Southern and Eastern U.S. and now share their identity with multiple states. In response, macrobreweries created "phantom crafts" to disguise some of their mass-produced offerings as craft in hopes to regain some of their recently lost control of the market. Coors had some success with beers like Blue Moon (Acitelli 2013, 206, Sullivan 2017). And when they could not make craft go away, they started to acquire. The unlimited potential for the craft industry eventually plateaued as some of the more lucrative breweries expanded beyond their means and ability. Several sacrificed independence by selling to larger corporations and macrobreweries in order to survive or grow. Others scaled back or simply stopped distribution altogether. Breckenridge, Avery, Oskar Blues, and recently New Belgium are no longer independently owned (Wallace 2015, Shikes 2020a). Access to craft beer outside the brewery has changed as well. In January 2019, a new statewide law allowed grocery stores and other retail outlets to sell full-strength beer. As a result, bigger craft breweries have benefited with increased availability and prominence on store shelves, while smaller breweries have struggled to get the same access for their products. Independent liquor stores, which have traditionally been a good place to find selections from smaller brewers, have been negatively impacted by these changes (Shikes 2020a). Craft breweries are also facing competition from other spirits as demographic changes have led to a shift in preference toward other adult beverages (Watson 2019).

Colorado's craft beer industry has had a fruitful history. From a few pioneers in Boulder and Northern Colorado, to the early success of brewpubs in mountain towns of the West, to an explosion of taprooms across the cities and suburbs of the Denver, Central, and El Paso regions, the industry has seen tremendous change over a short period. Whether or not growth will continue in the near future remains to be seen, but craft beer certainly has had a viable and important impact of the state's economy and tourism. More breweries are opening in close proximity to others, creating destinations for craft culture. At the same time, they are expanding into new, more dispersed communities across the state, giving better access to previously underrepresented populations. As some of the more established breweries move away from independence, younger and smaller breweries are creating innovative beers for a new generation and reshaping Colorado's craft beer identity. Despite the ups and downs of the past 40 years, the industry has solidified its footprint in the state with over 400 breweries continuing to offer both new and familiar experiences for those seeking Colorado craft beer and the spaces that create it.

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Glossary

Ale – beer conditioned at warmer temperatures (Oliver 2011).

Brewpub – sells 25% or more on site and operates significant food services (Brewers Association 2019).

Hazy – beer characterized by a cloudy appearance.

Imperial – beer characterized by high alcohol by volume (Oliver 2011).

Independence – less than 25% of the brewery is owned or controlled by a beverage alcohol industry member that is not itself a craft brewer (Brewers Association 2019).

India Pale Ale (IPA) – ale characterized by high levels of alcohol and hops (Oliver 2011).

Lager – beer conditioned at lower temperatures (Oliver 2011).

Macrobrewery – produces more than 6,000,000 barrels per year.

Microbrewery –produces less than 15,000 barrels per year and sells 75% or more off-site (Brewers Association 2019).

Porter - ale distinguished by darker color typically made from malted barley (Oliver 2011).

Regional – produces between 15,000 and 6,000,000 barrels annually (Brewers Association 2019).

Seltzer – clear, fermented alcoholic beverage containing carbonated water and often fruit flavoring.

Session – beer characterized by low alcohol suitable for extended periods of consumption.

Sour – beer with an intentionally acidic or sour taste (Oliver 2011).

Stout – ale distinguished by darker color and roasted characteristics typically made from unmalted barley (Oliver 2011).

Taproom – sells 25% or more on site and does not operate significant food services (Brewers Association 2019).
Wheat – beers made with a larger proportion of wheat relative to malted barley (Oliver 2011).

References

Acitelli, T. 2013. *The audacity of hops.* Chicago, IL: Chicago Review Press.

Barker, D. 2020. Craft beer loses its cool. *Crain's Chicago Business,* January 3. https://www.chicagobusiness.com/consumer-products/craft-beer-loses-its-cool.

Beer Advocate 2019. Accessed December 9, 2019. https://www.beeradvocate.com/.

Beer Me 2019. Accessed December 9, 2019. https://beerme.com/.

Boulder Beer 2019. Accessed December 9, 2019. https://boulderbeer.com/.

Brewers Association 2019. Accessed December 9, 2019. https://www.brewersassociation.org/.

Burke, E. 2019. New Belgium's Fat Tire gets new look. Accessed March 19, 2019. https://www.craftbeer.com/news/brewery-news/new-belgium-brewings-fat-tire-beer-gets-new-look.

Colorado Brewer's Guild 2019. Accessed December 16, 2019. https://coloradobeer.org/.

Colorado Brewery List 2019. Accessed December 16, 2019. https://www.coloradobrewerylist.com/.

Colorado Department of Local Affairs 2019. Colorado State Demography Office. Accessed December 9, 2019. https://demography.dola.colorado.gov/.

Fletchell, A. M. 2016. Place-Making Through Beer-Drinking: A Case Study of Montana's Craft Breweries. *Geographical Review 106* (4):539-566.

Frank, J. 2019. *Beer Lover's Colorado.* Guilford, Connecticut. Globe Pequot.

Great American Beer Festival 2019. Accessed December 12, 2019. https://www.greatamericanbeerfestival. com/.

Mathias, B.D., A. Huyghe, C.J. Frid, and T.L. Galloway. 2015. An identity perspective on coopetition in the craft beer industry. *Strategic Management Journal 39* (12): 3086-3115.

McLaughlin, R.B., N. Reid, and M. S. Moore. 2014. In *The geography of beer*, pp. 131-154. Dordrecht: Springer.

Oliver, G. 2011. Craft brewing. In *The Oxford companion to beer,* ed. G. Oliver. Oxford University Press.

Quintana, J. 2016. Crafted places: The use of place in Wisconsin craft beer marketing. MA thesis, University of Denver.

Rate Beer 2019. Accessed December 9, 2019. https://www.ratebeer.com/.

Schnell, S. M. and J. F. Reese. 2014. Microbreweries, place and identity in the United States. In *The geography of beer*, pp. 167-187. Dordrecht: Springer.

———. 2003. Microbreweries as tools of local identity. *Journal of Cultural Geography* 21 (1):45-69.

Sealover, E. 2016. *Colorado excursions with history, hikes, and hops.* Charleston, SC: The History Press.

Shikes, J. 2016. Meet the men who've visited all 300 breweries in Colorado. *Westword Magazine*, December 13. https://www.westword.com/restaurants/meet-the-men-whove-visited-all-300-breweries-in-colorado-8591297.

———. 2018. More Colorado breweries are closing, what does it mean? *Westword Magazine*, April 17. https://www.westword.com/restaurants/blind-faith-brewing-will-close-in-littleton-on-february-9-11624743.

———. 2019a. The thirty most important beers in Colorado history. *Westword* Magazine, October 1. https://www.westword.com/restaurants/beer-here-the-thirty-most-important-beers-in-colorado-history-11498154.

———. 2019b. How many breweries can Denver support? Finally, we may have the answer. *Westword Magazine*, December 10. https://www.westword.com/restaurants/denver-saturation-point-for-breweries-may-finally-be-reached-11563471.

———. 2020a. The ten biggest Colorado craft-beer stories of last year. *Westword Magazine*, January 2. https://www.westword.com/restaurants/the-biggest-colorado-beer-stories-of-2019-11584978.

———. 2020b. Boulder Beer company will close entirely – ending forty years of history. *Westword Magazine*, January 6. https://www.westword.com/restaurants/boulder-beer-company-will-close-entirely-ending-forty-years-of-history-11600857.

———. 2020c. Dale's Pale Ale loses its mountains in first can redesign in fifteen years. *Westword*

Magazine, January 7. https://www.westword.com/restaurants/oskar-blues-dales-pale-ale-gets-first-label-overhaul-in-fifteen-years-11595649.

Shilton, A. C. 2019. Dirtbags were the original craft-beer influencers. *Outside Magazine*, October 13. https://www.outsideonline.com/2402883/craft-beer-phenomenon-dirtbags.

Shumway, K. 2018. Beer business finance: breaking down the taproom-focused brewery model. *Brewbound*, October 12. https://www.brewbound.com/news/beer-business-finance-breaking-down-the-taproom-focused-brewery-model.

Sullivan, M. 2017. Beer goggles: looking at Colorado's cultural, economic, and social developments in the late twentieth century through the lens of its brewing industry. BA thesis, University of Portland.

Wallace, A. 2015. Breckenridge Brewery sold to giant Anheuser-Busch's "High End". *Denver Post*, December 22.

Watson, B. 2018. Changes to craft brewer definition won't greatly affect data set. *Brewer's Association*, December 18.

———. 2019. The state of craft in the state of craft: a contradictory market. Paper presented at the 3rd Annual Colorado Craft Brewers Summit, Fort Collins, Colorado, November 5.

Wolinski, C. 2018. Beer collaborations are cool, creative, and sell a lot of beer. *Vine Pair*, April 19. https://vinepair.com/articles/collaboration-nation/.

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FROM MINING TO TOURISM: SOCIO-ECONOMIC CHANGES IN THE COLORADO HIGH COUNTRY

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Introduction

The present chapter reconstructs long-term economic and social changes in the Colorado High Country: the transition from mining to tourism. It is argued here that a large number of historic mining towns located in the "Colorado Mineral Belt" such as Aspen, Breckenridge and Telluride as well as Black Hawk, Central City and Cripple Creek have seen a complete transition to tourism services—as ski and mountain resort towns or casino gambling centers respectively.

First, an overview of the gold rush in the late 1850s/1860s and of the silver boom from 1879 to 1893 will be given. Included is a discussion of the importance these early precious mining activities had for the State of Colorado. The ultimate demise of mining began in the early 1900s with few active mining areas remaining by the 1960s/1970s. Tourism to the Central and Southern Rockies had economically and socially replaced mining.

Though, the mining narrative continues to be influential. This will be shown for a number of places with mine tours and sites where the mining era can be revisited. It constitutes a viable form of heritage tourism in Colorado.

In the following the beginnings, growth and changes of the Colorado ski resort industry will be reconstructed. Skiing and snowboarding have become recreational activities with considerable economic impact.

In the last section of the chapter most recent changes in the corporate structure of the mountain resort industry, dominated by two major groups in North America, Vail Resorts Inc and the Alterra Mountain Company both headquartered in/near Denver, will be discussed.

The Colorado Mineral Belt: The Importance of Precious Metal Mining for the Early Development of the State of Colorado

Mining was the most significant industry in nineteenth and early twentieth century Colorado. The Pikes Peak Gold Rush of 1858/59 brought tens of thousands of gold prospectors to Colorado with tremendous implications for economic and social change. It would also lead to the creation of the Colorado Territory in 1861 culminating in the admittance of Colorado to the Union in 1876 (History Colorado 2019).

The basis for successful precious metal mining was the 400 km long Colorado Mineral Belt running diagonally across central and southwestern Colorado. The belt, rich in ore deposits, dates back geologically to the Precambrian through the Laramide orogeny in the late Cretaceous and early Tertiary. The principal mining districts of Laramide age are in the inner area bounded by solid lines and darker in color. The "maximum boundary" is shown by the dashed lines (see Figure 1 as discussed by Tweto and Sims 1963 and Wilson and Sims 2003).

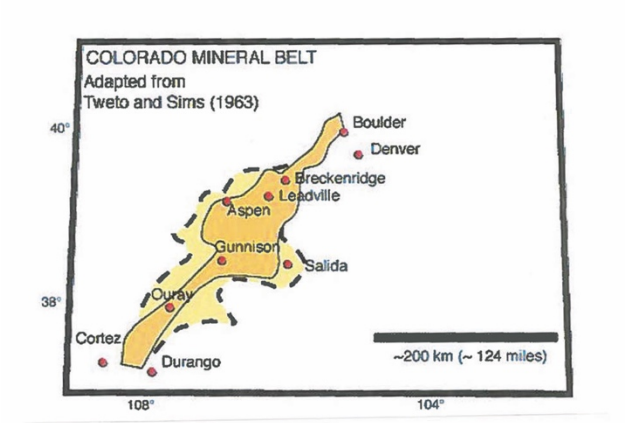

Figure 1. Colorado Mineral Belt. Adapted from Tweto and Sims (1963).

Gold was originally mined in the form of placer mining, then as lode and hard rock mining by extracting the gold veins from inside the mountain. Eventually, gold-rich veins were recovered from the deeper sulfide ores which required technologically advanced smelting operations. The volume of recovered gold differed over the years as mining operations

frequently followed the ups and downs of the national economy. Thus, mining for gold in leading producer areas in the Colorado Mineral Belt (Central City, Black Hawk and Idaho Springs, Breckenridge, the Alma-Fairplay district in South Park, Leadville as well as Ouray and Telluride in SW Colorado) experienced 'booms and busts.' After the initial gold discoveries in the late 1850s/early 1860s and the years with early smelter operations in the 1870s, an important time period for gold mining was the years 1895 (666,000 ounces or 18.880 metric tons) to 1900 (with a peak production of 1.4 million ounces or 39.689 metric tons). This last significant gold boom in Colorado occurred in Cripple Creek and Victor, mining towns outside the Colorado Mineral Belt. In the 1960s, gold production in Colorado decreased to 66,000 ounces or 1.871 metric tons (1960) and to 22,000 ounces or 0.623 metric tons (1967).

Silver mining became a crucial part of the Colorado economy in the late 1870s and 1880s. It reached a peak situation in the early 1890s. Leadville was the leading silver mining area with early findings in 1879. Other important silver mining towns were Aspen and Georgetown. The "silver boom" in Colorado was limited to about fifteen years. Government decisions (the congressional Bland-Allison act of 1878) marked the initial start as well as the end, with the repeal of the Sherman Act in 1893, which resulted in the collapse of silver prices (Western Mining History 2019).

Other precious metal mining activities were directed to the recovery of zinc, copper and, more recently, molybdenum, a metal important for the enhancement of steel. It resulted in an on and off production situation in two "moly" mining areas (Climax near Leadville and the Henderson Mine near Empire). By the 1950s, mining for uranium became a successful activity in particular in the southwestern border region to Utah. Currently none of the uranium mines are considered active production areas. In the 1990s (until 2001), Colorado had an active diamond mine near the Wyoming border which is now defunct.

The mining of metals gradually and consistently diminished in the last few decades all over Colorado, whereas coal mining has remained active in about ten places. Though, production of coal in Colorado has fallen, with the recent or prospective closure of more coal fired power plants in the state. The future of coal "looks increasingly grim" (Best 2019), as Tri-State Generation, a major energy provider, plans to close all its Colorado coal powered plants by 2030 in accordance with its Responsible Energy Plan (Paul 2020). The falling coal production, which is expected to accelerate in the next few years, is largely due to the greater uses of natural gas and renewable energy sources.

With the exception of a few active mining operations, e.g. in Cripple Creek/Victor (gold), on and off production at the Henderson Mine and Climax (molybdenum) and at a uranium mine near Uravan, mining has lost its once dominant role in the local economies. Still, there are several mining companies, most prominently the Newmont Goldcorp Corporation, the world's largest gold mining company, which have chosen for their headquarters a location in the Denver Metro Area. Newmont has approximately 24,000 employees and contractors worldwide.

While precious metal mining no longer constitutes a livelihood for Coloradans except a small minority, the mining era has left a resounding legacy in the Colorado High Country. Heritage tourism to former mining camps, towns and mills is alive and well; the mining narrative continues to affect local identities and has a significant economic impact in selected areas. About 20 Colorado towns and settlements have historic districts with protected remains of the mining era. They range from large and complex town sites such as the Central City—Black Hawk Historic District in Gilpin County to the fairly small Gold Hill Historic District, one of the earliest mining camps in Boulder County. A multitude of mining tours are offered on a regular basis, from jeep tours, for instance high up in the Tin Cup area, to visits to mining artifacts in preserved sites or in museums, like the Leadville National Mining Hall of Fame and Museum (History Colorado 2019). One of the phenomena surrounding the enduring fascination with mining history are visits to "ghost towns" like Ashcroft near Aspen, Nevadaville near Central City and St. Elmo near Buena Vista. Some of the defunct mills, such as the historic Argo Gold Mill & Tunnel in Idaho Springs, have been reopened to visitor traffic, with regular tours and further tourism development plans (Dallas 1985; Argo Mill & Tunnel Tour 2017; Blevins 2018; Colorado Tourism Office 2019). Finally, it should be mentioned that former mining cabins and structures are being used for recreational purposes. Mining shacks in the Alma-Fairplay area in Park County now serve as backcountry ski huts (Blevins 2019).

The Colorado Ski Resort Industry from the 1920s to 2020: Beginnings, Trends and Transitions

Skiing saw early forms of development in the 1920s and 1930s, when Colorado ski clubs such as the Colorado Mountain Club in Golden and the Zipfelberger Ski Club in Denver emerged to promote the new skiing sport in several Colorado locations. It was the immense popularity of ski jumping that first caught the attention of the public in Colorado. Regular competitive events were held in a half-dozen places with ski jumps including Dillon, Hot Sulphur Springs and at Howelsen Hill in Steamboat Springs. Downhill skiing became a trendier activity later in the 1930s, for instance at Loveland Basin (1936) and Berthoud Pass (1937), with the first rope tows, and at Aspen Mountain, with the Roche Cup, the first racing cup in Colorado. The establishment of Winter Park Resort, a City and County of Denver venture in 1939 with chair lifts and a convenient train connection to Denver, was crucial for popularizing skiing along the Front Range. The 10th Mountain Division, the "soldiers on skis," at Camp Hale and practice grounds near Leadville in the Colorado High Country (1943-1944) had lasting and far-reaching implications. After World War II, many of the 10th Mountain soldiers came back to Colorado to help build the new ski resort industry (Hart 2019; Stevens 2019). In the late 1940s and 1950s, Aspen became the leading resort town and the first destination ski area in Colorado. Tenth Mountain Division veteran Friedl Pfeifer, industrialist Walter Paepke and wife Elizabeth transformed the old silver mining town into an outstanding winter sports center with an upscale cultural festival in the summer. Under Pfeifer's and Paepke's leadership the Aspen Skiing Company was founded; the company installed the then world's longest chair lift in 1946-47. Moreover, the town hosted the first World Alpine Ski Championships in the U.S. in 1950. Other ski areas, from Arapahoe Basin (1946), Breckenridge (1961), Vail (1962), Steamboat (1963), Keystone (1970) to Telluride (1972), sprang up and rapidly developed. Colorado as a major skiing destination in North America had arrived.

By the mid-late 1980s, about 25 commercial ski areas (see Figure 2), with modern forms of uphill transportation (double or quad chair lifts including faster detachable ski lifts as well as gondolas) and snow making/grooming equipment, formed "Colorado Ski Country USA", a non-profit marketing organization. In the 1990s, snowboarding became a popular activity. The number of skier days (persons

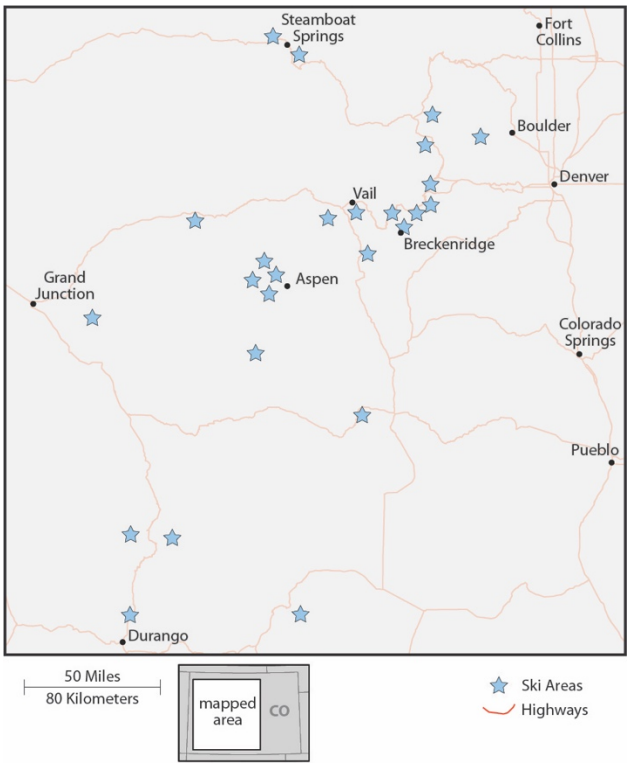

Figure 2. Colorado ski areas. Cartography by Peter Anthamatten.

purchasing lift tickets) at Colorado's commercial ski areas surpassed 10 million. It has gradually increased to currently 12 to 13 million annually. The ski industry in the Colorado High Country has become a major source of income—$4.8 billion annual impact to Colorado according to a 2015 study (Colorado Ski Country U.S.A. and Vail Resorts 2015)—with considerable benefits to the tax basis as a result of the local services provided to incoming visitors. Skiing and snowboarding support more than 46,000 year-round equivalent jobs in the amusement and recreation, lodging, food services, retail, and other sectors. These jobs generate $1.9 billion per year in labor income for Colorado. Many of the now nationally and internationally known destinations, including Vail, Aspen, Snowmass, Breckenridge, Steamboat Springs and Keystone, have developed into four season resort environments where tourists arrive year-round. Cultural programs in the summer season as well during the shoulder seasons have enriched community life in the resort towns. Meanwhile popular summer recreation activities such as mountain biking, zip-lining and alpine slides/ mountain coasters have created new income sources for the resort industry in the Colorado Rockies.

Tourism has become the second most important industry in the state's economy. Total travel spending in Colorado during 2018 was over $22.3 billion; travel spending directly supported over 174,000 jobs and earnings of over $6.8 billion (Dean Runyan Associates 2019). Tourism is largely considered a clean industry, whereas mining activities in the Colorado High Country have frequently created toxic pollutants from the uses of lead and arsenics in a multitude of locations. These sites are often visible as open mine tailings or as large abandoned mine sites. There are also several EPA Superfund sites, such as the Eagle Mine in the former Gilman mining town near Minturn, which still needs to be cleaned up. Though, ski resort development has at times also caused environmental concerns. In the early 1970s the Colorado electorate rejected the invitation to host the Winter Olympics Games of 1976 partially due to environmental concerns. In the mid-late 1990s Vail Resorts applied for the Category III Expansion into the Back Bowls of Vail Mountain. The National Forest Service approved their expansion of skiable terrain by 885 acres. Environmental groups in Colorado feared serious and lasting impacts on existing wildlife corridors. The public debate over the expansion culminated in an arson attack in October 1998. Seven structures on the mountain, including the large Two Elks building, went up in flames. Members of the Earth Liberation Front claimed that the new terrain in the back country would threaten the endangered Canada lynx. In the following years, the Town of Vail and Vail Resorts embraced a sustainability philosophy including the goal of the exclusive use of renewable energy sources by 2030 (Childers 2012; Town of Vail 2009; Blevins 2017; Hartmann 2017). Recently, the debate over the environmental impact of air travel has caused Aspen/Pitkin County to implement emissions-reducing projects (Aspen Airport 2018; Auslander 2020). While the objectives and goals of a sustainable future for the Colorado High Country have been formulated by several mountain town governments and agencies as well as the ski resort industry, their timely implementation remains elusive to date.

Equity issues are another major problem of ski resort development. Employees can no longer afford to live in the core resort areas, such as Vail Village and Beaver Creek in Vail Valley (Best 1998; Hartmann and Broadway 2018). They have relocated to less expensive housing areas in what has been termed the "Down Valley." Meanwhile the urbanized corridor of Vail Valley has expanded to over fifty miles (see Figures 3, 4, and 5, with photographs of different Vail Valley sections). Despite the establishment of subsidized employee housing complexes, affordable living conditions in the Colorado High Country continue to be a major issue, for the perennial "ski bums" attracted to the amenities and to the mostly Latino seasonal workers who do the manual jobs.

Figure 3. High density development at Lionshead in Vail Valley, with view toward Golden Peak, Vail Mountain and Vail Village. Photo: Copyright R. Hartmann and J. Kuroiwa.

Figure 4. Low density residential development near Beaver Creek Golf Course and Ski Area. Photo: Copyright R. Hartmann and J. Kuroiwa.

Colorado's Ski Resort Industry in the Global Economy

Over the past few years the ski resort industry in North America has seen major mergers. Many of the changes in resort ownership have been initiated by resort entities in Colorado. Vail Resorts Inc., since 1997 a corporation on the New York Stock Exchange with the ownership of then four Colorado ski resorts (Vail, Beaver Creek, Breckenridge and Keystone), moved its headquarters out of Vail Valley to the Front

Figure 5. Trailer Park for seasonal employees in Edwards in the 'Down Valley.' Photo: Copyright R. Hartmann and J. Kuroiwa.

Range in 2006. In 2007, the company launched its new Epic (season) Pass. Since then, Vail Resorts has acquired a total of 37 ski resorts in the U.S., Canada and Australia. The Epic Pass is now (December 2019) valid in over 79 ski resorts including Japan, Chile, France, Italy, Switzerland and Austria. In January 2018, a competitive group of ski resorts, Alterra Mountain Company, was formed. It was created as a collaborative conglomerate of ski resorts under the leadership of KSL Capital Partners (Squaw Valley, Mammoth and other California/Nevada ski resorts) and the four Aspen ski areas (owned by the Crown Family). By December 2019 the group has expanded its collaboration to 14 ski resorts. Their Ikon (season) Pass is now (December 2019) valid in 41 ski locations. While the two groups have started to pinch the smaller 'mom and pop' operations in North America, the new corporate landscape has also been hailed by ski consultants and observers. Chris Diamond, former owner of the Steamboat Springs ski area, calls it a "North American renaissance (of the ski industry)" (Diamond 2019). In Colorado seven ski resorts use the Epic Pass and eight the Ikon Pass. The skiing public can purchase the passes under different conditions, from unlimited use of all ski resorts to a more selective and restrictive resort area availability with blackout dates. Both rival giants, which fiercely battle for increased market share, have their headquarters in the Denver Metro Area (Broomfield and Denver respectively). The two headquarters, with bases in Colorado, reflects a trend towards a globalization of the mountain resort industry. Vail Resorts and Alterra are companies with a global reach.

Conclusion

The Colorado High Country has seen fundamental changes regarding its economic base. Precious metal mining in the Colorado Mineral Belt was the most significant industry in the early days of Colorado, thus helping to establish a new territory (1861) and the Centennial State of the Union (1876). During the past few decades, services for recreation and tourism in the mountain environment have become a dominant part of the economic livelihood of Colorado households, in particular on the Western Slope. With the rise of the ski resort industry Colorado gained nationwide and international recognition. Vail Resorts and Alterra, two large ski companies with headquarters on the Colorado Front Range, now provide the main seasonal ski passes for the skiing public in North America. The mining era, though, is hardly forgotten. The narrative of the gold and silver mining years has become a viable base for the celebration of this legacy. The providers of heritage tourism to twenty historic mining districts as well as the owners and managers of 25 commercial ski areas in the Colorado Rockies have made efforts to implement an agenda for a sustainable future of the Colorado High Country.

References

Argo Mill and Tunnel. 2017. Tunnel of Gold: The Argo Tunnel reopens to visitor traffic. https://argomilltour.com/argo-tunnel/.

Aspen Airport. 2018. Airport improvements overview. *ASEVISION*, November 5. https://aspenairport.com/airport-improvements-ea/ summary/.

Auslander, J. 2020. Pitkin County to promote green air travel with program to offset environ-mental impact. *Aspen Times*, January 1.

Best, A. 2019. For Colorado energy provider, the future of coal looks increasingly grim. *Energy News U.S.* https://energynews.us/2019/11/04/west/for-colorado-energy-provider-the-future-of-coal-looks-increasingly-grim/.

Best, A. 1998. Vail and the road to a recreational empire. *High Country News* 30 (23):10-15.

Blevins, J. 2019. Old mining shacks are becoming backcountry ski huts in Colorado's High Country. *Colorado Sun*, December 26.

Blevins, J. 2018. How Idaho Springs plans to turn the Argo Mine Superfund site into a tourist attraction. *Denver Post*, January 1.

Blevins, J. 2017. World's largest operator vows to be clean by 2030. *Denver Post*, July 29.

Childers, M. 2012. *Colorado powder keg: Ski resorts and the environmental movement*. Lawrence, KS: University of Kansas Press.

Colorado Tourism Office 2019. Colorado Mine Tours and Gold Rush Towns. https://www.colorado.com/articles/colorado-mine-tours-gold-rush-towns/.

Colorado Ski Country USA. and Vail Resorts. 2015. Economic study reveals ski industry's $4.8 billion annual impact to Colorado. https://www.coloradoski.com/media_manager/mm_collections/view/183.

Dallas, S. 1985). *Colorado ghost towns and mining camps*. Norman, OK: University of Oklahoma Press.

Dean Runyan Associates (2019). *Colorado Travel Impacts 2000 – 2018p*. Denver, Colorado: Colorado Tourism Office June 2019, 59 pp.

Diamond, Chris (2019). *SKI INC 2020: Alterra counters Vail Resorts; the industry responds and flourishes. For skiing? A North American Renaissance*. Steamboat Springs: Ski Diamond Publishing.

Hart, M. (2019. The 10th Mountain Division—the ski industry catalyst. *Mountain Town*. https://mtntownmagazine.com/the-10th-mountain-division-the-ski-industry-catalyst/.

Hartmann, R. 2017. The World Alpine Ski Championships 1989, 1999 and 2015 in Vail, Colorado: Impacts, issues and the quest for sustainable resort development, *International Journal of Research in Tourism and Hospitality* 3 (3):43-53.

Hartmann, R. and S. Broadway. 2018. Vail: Explaining growth dynamics of a Colorado Ski Resort Town. *International Journal of Tourism Sciences* 18 (4):279-294. doi:10.1080/15980634.2018.1551314.

History Colorado 2019. The Mining Industry in Colorado. https://www.historycolorado.org/mining-industry-colorado.

Pau, J. 2020. Tri-State Generation to close all of its Colorado, New Mexico coal-fired power plants and coal mines–3 locations–by 2030. *Colorado Sun*, Jan 9. https://coloradosun.com/2020/01/09/tri-state-close-colorado-coal-fired-power-plants/.

Stevens, M. 2019. The Legacy of the 10th Mountain Division, Part 2: Ski towns and industry. https://www.usrepresented.com/2018/05/19/10th-mountain-division-part-2/.

Town of Vail. 2009. *Code green—Building a sustainable future*. Vail: Town of Vail.

Tweto, O. and P.K. Sims. 1963. Precambrian ancestry of the Colorado mining belt. *Geological Society of America Bulletin* 74 (8):991-1014.

Western Mining History. 2019. The Colorado Silver Boom. https://westernmininghistory.com/articles/9/ page1/.

Wilson, A.B. and P.K. Sims. 2003. Colorado Mineral Belt revisited—An analysis of new data. Open-File Report 03-046. U.S. Geological Survey, Denver, CO.

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OBTAINING AND RETAINING HISPANIC MIGRANT LABOR IN THE 1920'S SUGAR BEET LANDSCAPES OF COLORADO

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The Sugar Beet Industry in Colorado: A Brief History

The sugar beet industry has a long and rich history in Colorado. The venture began in March 1871 when *The Rocky Mountain News* ran the headline "Plans to establish beet sugar industry." Access to irrigation systems along the South Platte River, as well as a suitable climate and fertile soils, prompted the industry to take root in the late 19th Century (Twitty 2003). In addition, sugar beet growing and processing began to expand in Colorado after passage of the 1887 Dingley Act, which increased tariffs to cane sugar, thus improving the competitiveness of beet sugar in both national and international markets.

Figure 1. Fort Collins Colorado Sugar Beet Factory – The Great Western Sugar Company (Independent Lumber Company Collection, Loyd Files Research Library, Museum of Western Colorado, 1982.101).

By 1909, Colorado was the largest sugar producing state in the United States, and significant inputs had been made to creating infrastructure which allowed the sugar beet landscape to prosper (May 1982; Reich 2008; Hamilton 2009; Norris 2009; Mitchell 2010). Companies like the Great Western Sugar Company (GWSC) established many sugar processing factories, especially in Colorado's northeastern region, using rail lines to link factories to outlying beet growers. As a result, a factory landscape emerged rapidly during the late 19th and early 20th centuries in Colorado (Figure 1). By 1927 there were

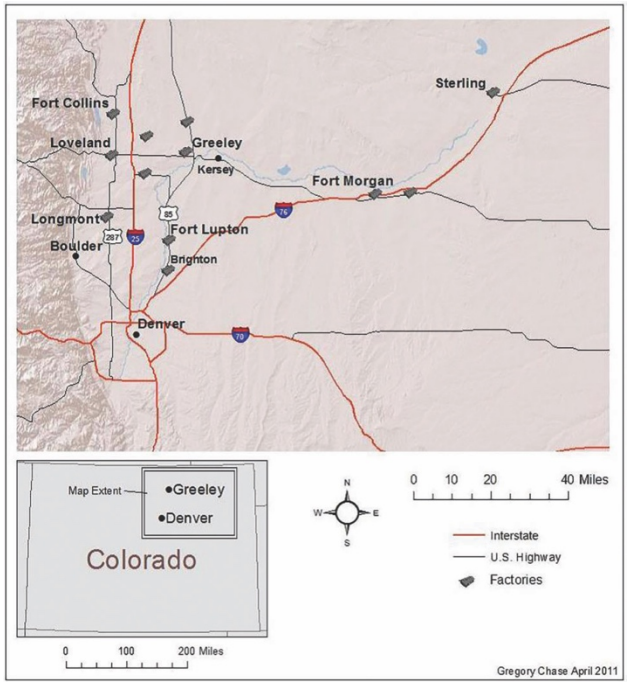

Figure 2. The distribution of sugar beet factories across northeastern Colorado.

13 sugar beet factories in northeastern Colorado. (Figure 2).

However, by the 1920s, northeastern Colorado lacked enough workers for either farm or factory work, and since sugar beet production was highly labor-intensive, companies like GWSC began to play a critical role in recruiting migrant laborers to work the required beet acreage. The company worked as liaisons, connecting farmers to recruiters, who then ensured the availability of large pools of mobile sugar beet laborers (Roskelley and Clark 1949; Peck 1996; Peck 2000). Indeed, GWSC's recruitment practices were critical in changing the demographics of Colorado, especially as their practices encouraged the significant expansion of the Hispanic population in the state.[1]

This chapter explores how GWSC obtained these Hispanic laborers while also actively pursuing a policy of permanent settlement, including the construction of subsidized housing, to retain year-round laborers. We are most interested in the period between 1910 and 1930, as this was a key era in the expansion and growth of the Hispanic population in the U.S., and in northern Colorado in particular. We use archives to explore as many available sources as possible to understand how the Hispanic community emerged in northeastern Colorado. One important source was the trade magazine *Through the Leaves* which GWSC printed and distributed to its farmers on a monthly basis during the 1920s (Figure 3). The magazine reported weather trends, beet prices, and other sugar beet news while also maintaining an ongoing dialogue about labor contracts and recruitment efforts. *Through the Leaves* provides a wealth of words, images, and representations of the sugar beet industry. Additionally, *The Sugar Press*, published for the employees of GWSC on a monthly basis, proved another useful source. The newsletter was mostly an outlet for the company to describe various goings-on of its factory employees (most of whom were U.S.-born in the early 20th century), rather than highlighting the lives of the field hands employed by GWSC and its farmers. We also sifted through dozens of reports on the labor conditions of agricultural workers in Colorado, along with oral histories and empirical surveys. Together this collection of material created a rich data source upon which to explore the key labor dynamics that came into play in producing and reproducing the sugar beet landscape.

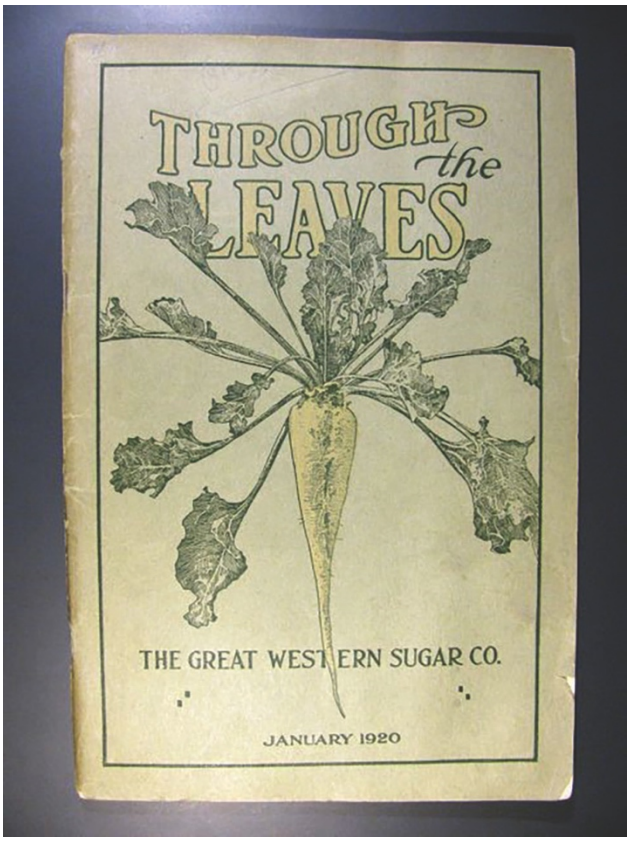

Figure 3. Typical cover of *The Sugar Press* (http://lib.colostate.edu/research/agbib/photos-leaves.html).

Obtaining Migrant Labor: The Influence of the Great Western Sugar Company

Initially, the migrant population that satisfied sugar beet farmer's labor demands was of German heritage from Russia. But in the 1910s, these German Russian migrant laborers began to demand higher wages and better working conditions (Cook 1978). To counter these demands, the sugar beet industry sought substitute labor sources, and eventually looked to the northern mountains of New Mexico, the borderlands of Texas, and the interior of Mexico for new supplies of workers. Especially by the 1920s, this desire for cheap agricultural workers began to draw substantial numbers of Hispanics to northern Colorado (Skop, Gratton, and Gutmann 2006).

There is evidence of this dramatic shift from German Russians to Hispanics in the archival data from the period, as shown in Figure 4. Taylor (1929) calculated that in 1909, 55% of sugar beet agricultural labor was comprised of German Russians and nine percent were Hispanic. By 1927, 59% of agricultural laborers were Hispanic. Meanwhile, 31% of agricultural laborers were German Russians. Hispanics became the dominant ethnicity of migratory beet labor throughout the Rocky Mountain growing region in a period of less than twenty years. A survey conducted in 1935 indicated that the segmented labor market had completely turned over to Hispanics, with 67% of the sampled head of households identifying as Hispanic (Johnson 1939). While Johnson (1939) does not delineate gender in his analysis, research by Skop, Gratton, and Gutmann (2006) confirms that while the preponderance of males was evident in initial immigration streams, female immigration quickly followed. Female immi-gration led to an overall balance by gender, declines in transitory household structure and the dominance of nuclear household

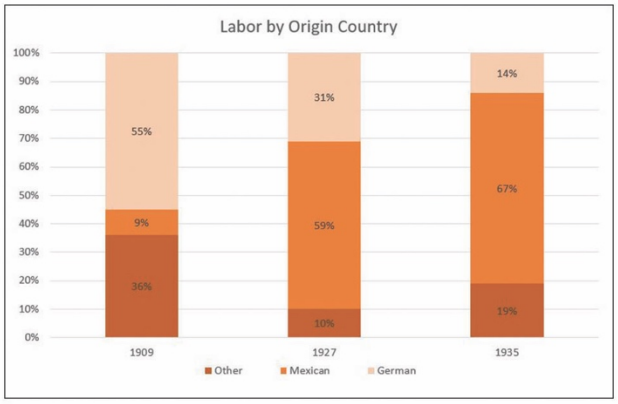

Figure 4. Changing demographics of sugar beet hand labor, 1909-1935. Adapted from Johnson 1939. It is unclear of the distribution of gender across this data. It is likely that "Mexican" includes Spanish speaking people from New Mexico and throughout the border regions of the United States.

patterns among persons of Mexican origin in the region by the end of the study period (Skop, Gratton, and Gutmann 2006).

So how did this demographic shift occur? As a private, profit-seeking agent of the migration industry, GWSC (along with other sugar industry companies) utilized its well-established recruitment system to obtain Hispanic laborers. GWSC employed a labor commissioner whose job was to recruit and deliver laborers. This commissioner in turn employed 55 sugar company labor agents; some worked seasonally or year-round, and some spoke fluent Spanish (Taylor 1929, 132). The recruitment process started in February and labor recruiters spent months traveling around the southwestern U.S. The recruiters canvased dozens of towns in search of the spring's sugar beet labor force. They held public meetings and went door-to-door, distributing informational booklets printed in Spanish. The goal was to either sign laborers up with sugar beet contracts or to put them in direct contact with Colorado farmers who handled their own labor contracts (*Through the Leaves* May 1928; Crane 1929).

While many of Hispanics hired were from New Mexico and the Southwest, Mexican nationals were also recruited (Taylor 1929, Thomas 2003a). The GWSC maintained recruitment offices in El Paso and San Antonio with the objective of hiring Mexican national seasonal laborers (Taylor 1929). Recruiting Mexican nationals already in the U.S. allowed them to avoid the complicated systems that controlled trans-border crossings at the time (Peck 2000).[2]

Known as *padrones*, *enganchistas, enganchadores*, or *contratistas* (Peck 2000; Griffith 2007; Hernández-León 2008), the recruiters worked for GWSC and acted as middlemen between immigrant laborers and farmers. Their job was to persuade laborers to travel the rails in acceptance of jobs offered by farmers contracted with GWSC. One-way transportation north was provided by GWSC for those migrating each spring to work the beet fields. For instance, "in 1926 transportation fares were provided for 14,500 persons who came by train or auto from eighteen states. Full fares for 10,800 workers and half-fares for 3,700 workers were paid by GWSC" (Taylor 1929, 132). The result was a dramatic seasonal increase in temporary migrant laborers in the sugar beet fields of Colorado.

Roskelley and Clark (1949) identified the complexity of factors driving Hispanic migration. Their 1939 survey conducted with the heads of 470 agricultural labor families in Colorado demonstrated just how important GWSC was to the recruitment of sugar beet laborers. For instance, when asked about who supported their migration, 34% said the sugar company. An additional 16% cited a friend as the source of encouragement to come to Colorado, nine percent cited a relative, 14% other, and five percent were born in Colorado.

Retaining Migrant Labor: The Influence of the Great Western Sugar Company

The annual recruitment push was an essential component in securing labor. It became increasingly recognized that ensuring the return of the best laborers was also advantageous to improve efficiency. Topics covered in *Through the Leaves* show the company's recognition that housing conditions, first for seasonal labor and later for year-round field laborers was identified as a crucial component to the retention and recruitment of their whole agricultural labor force.

Summer Temporary Housing

Miserable conditions dominate the writing that describes temporary housing inhabited by Hispanic sugar beet laborers in Colorado (Mahony, Dolan, and Fitzgerald 1927). Not only was the work demanding, but housing was dismal. Structures owned either by the farmer or the sugar beet company, commonly referred to as "beet shacks" housed many of the laborers (Figure 5). The housing varied from "reasonably good and attractive to almost unbelievably poor…

[where some did] not meet any standard of health, protection, or comfort" (Roskelley and Clark 1949, 17). Of the 100 houses surveyed by Roskelley and Clark, 76 had poor leaking roofs, 23 had no foundation or an inadequate one, and 12 had dirt floors. Twenty seven percent of families carried water for cooking over 100 feet, 14% over 250 feet.

Figure 5. A characteristic "Beet Shack" compared to permanent housing funded by the Great Western Sugar Company (Cooper 1920).

In 1920, in the *Through the Leaves* article "Beet Shacks vs. Beet Houses" Cooper (1920) explained that potential laborers kept asking recruiters specific questions about the quality and size of the housing associated with their beet contracts. They were also asking about the quality of water available. Potential laborers were turning down labor contracts with unacceptable housing conditions. Similarly, outside groups expressed a concern regarding labor relations. Thomas Mahoney, of the Mexican Welfare Committee of the Colorado State Council, argued that it was only a matter of time before Hispanic beet laborers organized themselves against miserable living and working conditions (Mahoney 1928).

Thus began a concerted effort by the GWSC to improve housing as a method to reduce recruitment costs and encourage the return of trained seasonal laborers. Recurrent articles appeared throughout the decade in *Through the Leaves* aiming to drive awareness and calling farmers to action to improve housing conditions in order to attract laborers to the fields. In the March 1920 issue: "The housing of our beet help is something that is of prime importance in the securing of good satisfactory labor for our growers, and is something that receives too little thought and attention by them as a whole" (Cooper 1920, 187). Another article title gets straight to the point: "Practicing a labor preachment: What the Great Western Sugar Company has been doing to save experienced beet workers for the growers" (*Through the Leaves* 1924). Clearly, GWSC was beginning to see the rationale for creating a permanent labor source through improved housing, perhaps in an effort to increase productivity of its laborers but also to keep labor costs low and squelch potential uprisings from the workers themselves.

Winter Permanent Housing

Despite company calls for improved housing, most temporary agricultural laborers continued to live in woeful circumstances, especially during sugar beet season. During the winter months, most beet laborers returned to homes away from the fields. Some laborers moved on in search of more agricultural work, some migrated back to Mexico or New Mexico, while others spent the winters in Denver, mostly in the lower-income pockets of the city along the South Platte River. Very few stayed in the towns near the sugar beet farms.

However, a second strategy employed by GWSC did increase the number of Hispanic families wintering in the area. Again, using *Through the Leaves* as a platform to transmit this message to their farmers, articles first called for farmers to winterize their summer labor housing and employ some of their laborers through the winter. Articles argued this housing would otherwise sit idle and empty through the offseason. *Through the Leaves* also printed building plans and instructions on a regular basis. The publication also urged farmers to have their employees build these houses after the prime beet season (Figure 5). Some farmers continued to see housing insecurity of beet labor not as inefficient but as a leveraging point, allowing them to maintain power over the laborers (Roskelley and Clark 1949). It may have been this sentiment that left GWSC's call for improved farmer-built housing mostly unheeded.

Following their own recommendations, GWSC proudly reported in October 1923 that they had begun "colonizing Mexican beet workers" in an effort to expand productivity. By the 1930s, Fort Morgan would become one of several important permanent Hispanic

laborer communities sponsored by GWSC. The company's other key settlements were in the Española Subdivision in Greeley and the Alta Vista neighborhood of Fort Collins (Figure 6).

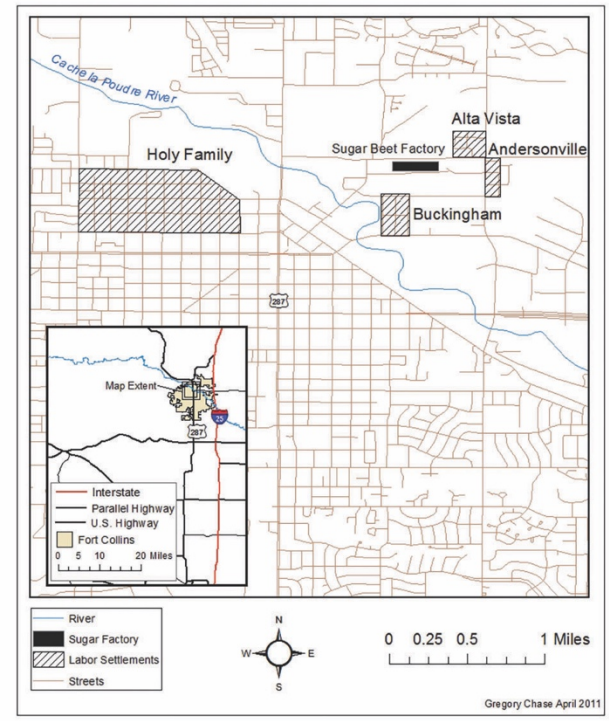

Figure 6. Fort Collins sugar Beet neighborhoods. Buckingham and Andersonville began as housing communities for German Russian workers and transitioned to Hispanic dominated communities (adapted from Thomas 2003b). Alta Vista was created by the Great Western Sugar Company for Hispanic field laborers and Holy Family transitioned into a Hispanic community.

Their efforts to build permanent housing correlates with the increasing numbers of Hispanic families who wintered in the area. GWSC reported that in 1921, 700 Spanish-speaking families wintered in Great Western districts. In 1922 the number was 1,000, and in 1923, there were 1,523 Spanish-speaking families (*Through the Leaves* November 1924). By 1927, the number of Hispanic families wintering in Colorado rose to 2,084 (Twitty 2003).

Thus, the increased rates of Hispanic residents in Colorado through the 1920s were not only the result of micro- and macro- level neo-economic forces and migrant social networks. Hispanic migration to Colorado also resulted from the strategic recruitment efforts of GWSC. According to one survey, nearly one third of the Hispanic sugar beet labor population cited the direct encouragement from the sugar company as the impetus for their decision to migrate and settle in Colorado (*Through the Leaves* November 1924). Clearly, GWSC's efforts to encourage settlement amongst Hispanic sugar beet workers had paid off, as increasingly established communities burgeoned throughout the northeast Colorado sugar beet landscape.

Conclusion

Due to the confluence of multiple social, economic and political factors, throughout the 1920s, more laborers stayed in northeastern Colorado, and permanent Hispanic enclaves developed on marginal lands at the fringe of many agrarian and factory towns. GWSC-sponsored *colonias* began to materialize in Greeley, Fort Collins, and several other sugar beet towns including Fort Morgan, Kersey, Johnstown, Hudson, Orchard, Brush, Ovid, and Sedgwick.

These conditions would change in the mid-1930s when events took a dramatic turn not only in the sugar beet landscapes of Colorado, but in the entire country. As the ongoing economic depression appeared to be unending, combined with growing animosity towards Hispanic laborers and diminished demands from employers, flows of immigration from the south came to a trickle, and even ended, for a short time period, from the mid-1930s to 1942 (Skop, Gratton and Gutmann 2006). Many laborers returned voluntarily, since the lack of job opportunities and a nativist backlash discouraged them from staying. Others (especially in California and Texas) were subject to forced repatriation (Hoffman, 1974; and Guerin-Gonzales, 1994). The U.S. government used this strategy with the hopes of easing public discord and the country's financial hardship. As a result, thousands were deported in the 1930s, including some Hispanic-American citizens born in the U.S. (Hoffman, 1974). The sugar beet laborers were no exception. The archives used for this research tell stories of banishment and heartbreak, as families once united in the sugar beet fields and migrant neighborhoods of northeastern Colorado faced separation and the anguish of deportation.

Even so, with the initiation of the Bracero program in 1942, old migration routes were renewed and new ones established, resulting in increased population densities of Hispanics not only in northeastern Colorado, but in other areas of Colorado as well. Fueled by immigration and natural increase, the ab-

solute and relative population of Hispanics rose through time, and the communities originally created by GWSC recruitment and retention activities remain to this day, even as the fields and factories that once grew and processed sugar beets have diminished, and in some cases, disappeared.

Notes

1. The article uses *Hispanic* to capture the Spanish-speaking people of northeastern Colorado, both those born in the United States and abroad. During the period of study, Mexican Americans and the Mexican born were the vast majority of the larger Hispanic population living in Colorado, though this research also unveils a rich history of family narratives from surrounding Hispano communities. This distinctive subgroup of Hispanics derive their cultural ancestry from the earliest Spanish colonial settlement of New Mexico, and their descendants continue to predominate in northern New Mexico and southern Colorado to this day (Nostrand 1970; 1993). Until this terminology came into existence in the 1970s, the academic literature and popular media lumped most Hispanos into the *Mexican* category (Gratton and Gutmann 2006). This was definitely the case in our review of archival materials, where the term *Mexican* predominates. Thus, in order to be most inclusive and accurate, this article uses the term *Hispanic.* It should also be noted that *Latino* and *Latinx* is more commonly utilized in contemporary discussion, since this term embraces both the Spanish-speaking and indigenous groups of Latin America (Rodriguez 2014).

2. These migratory systems emerged as a result of the U.S. Immigration Acts of 1917 and 1924 which required foreign individuals crossing the border to take literacy tests, undergo medical exams, and pay head taxes and visa fees. In order to avoid these constraints, and because it was often cheaper, migrants would pay a coyote to get across the border (Peck 2000). The new requirements combined with the creation of the Border Patrol in 1924, prompted thousands of Mexican migrants to cross the Rio Bravo surreptitiously to enter the country (Spener 2009). Spener cited The U.S. Commissioner of Immigration and their observation that the introduction of Mexican immigrants was a thriving and organized industry. Once the migrants were across the border, they waited for other members of the migration industry, particularly labor recruiters in El Paso and San Antonio, to negotiate and be delivered to jobs throughout the U.S. (Spener 2009).

References

Cook, G.A. 1978. Fact and fiction: German Russian sugar beet farmers in Colorado. In *Germans from Russia in Colorado*, ed. S. Heitman, 4-16. Ann Arbor, Michigan: The Western Social Science Association.

Cooper, F.L. 1920. "Beet shacks" vs. beet houses. *Through the Leaves*. March.

Crane, T.J. 1929. Ten years of recruiting labor. *Through the Leaves*. October.

Gratton, B. and M. P. Gutmann. 2006. Hispanic population. In *Historical statistics of the United States*, ed. S. B. Carter, S. S. Gartner, M.R. Haines, A. L. Olmstead, R. Sutch, and G. Wright, 160-181. New York: Cambridge University Press.

Griffith, D. 2007. Guestworkers, *Enganchadores* and the changing labor relations in U.S. rural communities. Paper prepared for the UC-DC Conference, Washington, D.C.

Guerin-Gonzales, C. 1994. *Mexican workers and the American dream: Immigration, repatriation, and California farm labor, 1900-1939.* New Brunswick, NJ: Rutgers University Press.

Hamilton, C. 2009. *Footprints in the sugar: A history of the Great Western Sugar Company*. Caldwell, ID: The Caxton Printers, Ltd.

Hernández-León, R. 2008. *Metropolitan migrants: The migration of urban Mexicans to the United States*. Berkeley, CA: University of California Press.

Hoffman, A. 1974. *Unwanted Mexican Americans in the great depression: Repatriation pressures 1929-1939*. Tucson: The University of Arizona Press.

Johnson, E.S. 1939. *Welfare of families of sugar beet laborers*. Washington: United States Printing Office.

Mahony, T.F. 1928. *5th annual report by the Mexican Welfare Committee*. Colorado: Mexican Welfare Committee, Colorado State Council, Knights of Columbus.

Mahony, T.F, F.F. Dolan, and D. L. Fitzgerald. 1927.

4th annual report by the Mexican welfare committee. Colorado: Mexican Welfare Committee, Colorado State Council, Knights of Columbus.

May, W.J. Jr. 1982. The Great Western Sugarlands: History of the Great Western Sugar Company. PhD diss., University of Colorado Boulder.

Mitchell, D. 2010. Battle/fields: braceros, agribusiness, and the violent reproduction of the California agricultural landscape during World War II. *Journal of Historical Geography* 36 (2): 143-156.

Norris, J. 2009. *North for the harvest: Mexican workers, growers, and the sugar beet industry*. St. Paul: Minnesota Historical Society Press.

Nostrand, R. 1970. The Hispanic-American borderland: Delimitation of an American culture region. *Annals of the Association of American Geographers* 60 (4):638-61.

Peck, G. 1996. Reinventing free labor: Immigrant *padrones* and contract laborers in North America, 1885-1925. *The Journal of American History* 83(3):848-871.

———. 2000. *Reinventing free labor: Padrones and immigrant workers in the North American West, 1880-1930*. Austin: University of Texas at Austin.

Reich, W.L. 2008. *Colorado industries of the past*. Boulder: Johnson Books.

Roskelley, R.W. and C.R. Clark. 1949. *When different cultures meet: An analysis and interpretation of some problems arising when people of Spanish and North European Cultures attempt to live together*. Denver: Rocky Mountain Council on Inter-American Affairs.

Skop, E., B. Gratton, and M. Gutmann. 2006. *La frontera* and beyond: Geography and demography in Mexican American history. *The Professional Geographer* 58 (1):78-98.

Spener, D. 2009. *Clandestine crossings: Migrants and coyotes on the Texas-Mexico border*. Ithaca, NY: Cornell University Press.

Taylor, P.S. 1929. *Mexican labor in the United States: Valley of the South Platte Colorado*. Berkeley: University of California Press.

Thomas, A. 2003a. *Work renders life sweet: Germans from Russia in Fort Collins, 1900-2000*. Westminster, Colorado: SWCA Environ-mental Consultants.

Twitty, E. 2003. *Silver wedge: the sugar beet industry in Fort Collins: A historical context*. Westminster, Colorado: SWCA Environ-mental Consultants.

Through the Leaves. 1923. Colonizing Mexican beet workers. October.

———. 1924. Practicing a labor preachment: What the Great Western Sugar Company has been doing to save experienced beet workers for the growers. November.

———. 1924. Growers are keeping their beet labor in increasing numbers each year. November.

———. 1928. When beets call to the back country: And you buck snow and quicksand slush to get a labor contract. May.

Western Sugar Cooperative. 2006. Available from http://www.westernsugar.com/harvestandstorage.html. Accessed 10 March 2014.

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RESILIENCE IN THE ROCKIES: CARVING A RECREATION FUTURE IN MARBLE, COLORADO

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Like many Colorado towns, Marble sprang to life around the extraction of natural resources, quarrying its namesake stone to build the Lincoln Memorial and other monuments in the East. Today, around 120 people live year-round in Marble, seeking a peculiar modern form of isolation in a place without cell service or Internet, surrounded by public lands and legislatively certified wilderness areas. In the summer, however, the Instagram-worthy peaks of the Maroon Bells draw more than 17,000 people through the gateway community, many of them driving off-highway vehicles (OHVs) on the Lead King Loop Trail (Figure 1). Hikers and mountain-bikers also use this rugged, 13-mile dirt road, but motorized recreation has put the region on the map, luring drivers of dirt bikes, off-road all-terrain vehicles (ATVs), and an increasing variety of "side-by-side" utility terrain vehicles (UTVs). As OHV tourism rises in popularity, residents of gateway communities, who themselves often use OHVs for personal transportation, experience impacts of noise, speed, and parking (Figure 2). Growing OHV use has physically altered the terrain, as larger and wider UTVs traverse a trail shaped over decades by narrow ATVs, eroding the road bed into the Crystal River and threatening the town's water quality. Residents who grumble about the motorized threat to their pastoral hideaway also face the real possibility that the trail which brings tourists to their community and dollars to their tax base is literally crumbling away.

Marble (Figure 3) faces multifaceted pressures from the recreation tourism economy and lacks social and economic resources to respond. Not only is the one-restaurant town isolated by high mountain passes, but it sits in the margins of political systems, a 3-hour drive from the county seat (more when the pass closes in the winter) and a similar distance from the management center of the White River National Forest. In 2019, the town of Marble convened a working group to evaluate infrastructure, quality of life, economy, and collective identity, in hopes of initiating a planning process for the Lead King Loop that can operate within this complex landscape to build resilience. Observing the formation and operation of the working group presents an opportunity to understand how planning processes cope with change, and the social and material outcomes of planning in citizen's lives. The case of Marble reminds us that planning is not a neutral process. In a state like Colorado which has experienced decades of recreation growth, examining the politics of recreation planning processes gives insight into how the place is made, creating the spaces and experiences that appear to visitors and residents alike as the "natural" way to experience the Rocky Mountains.

Figure 1. OHVs motor out of Marble, following the Crystal River to the near-"ghost" town of Crystal and on to the Lead King Basin. Photo by Corinne Truesdell.

Colorado: The State of Recreation

Colorado's governing bodies have actively encouraged the growth of the recreation sector. The Colorado Outdoor Recreation Industry Office, established in 2015, is one of just 11 in the nation that advocates and accrues resources to support the

Figure 2. Vehicles cram into every available parking spot—and make some new ones—during September's Marble Fest. Photo by Corinne Truesdell.

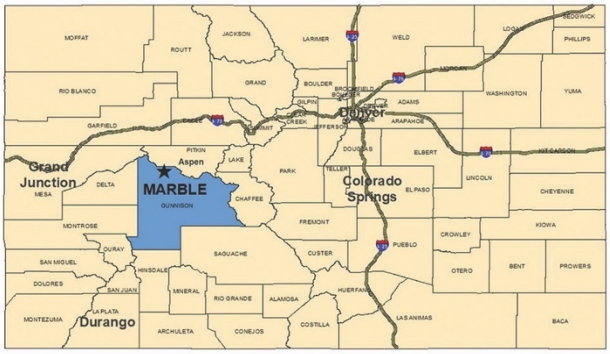

Figure 3. Marble, Colorado. Cartography by Jennifer Fenwick and Blaine Hartman.

recreation economy. When retailers threatened to boycott the major outdoor retailer trade show, held in Utah for 20 years, due to Utah's position on Bear's Ears National Monument, Colorado's public courtship of the show promised to bring millions of dollars of direct and indirect spending. Rationales for promoting recreation are largely centered on economic and cultural gains. The Bureau of Economic Analysis reported the value of the outdoor recreation industry in the United States at $427 billion annually, or two percent of the U.S. gross domestic product (Bureau of Economic Analysis 2019). Recreation expansion is also framed as an alternate or complement to unstable resource extraction economies and a source of rural employment outside of agriculture, both of which have been cornerstones of Colorado's economy.

Communities centered on recreation have been an anomaly in the trend toward increased urbanization since the recession in the U.S. ended in 2010. While much of rural America is losing residents faster than it gains them, there has been a slight growth in population in recreation-centered counties (Headwaters Economics 2019; Henderson and McDaniel 2005). Moreover, people moving to these counties have above average household incomes. Despite the positive economic gains, the benefits of recreation are contested. Rapid growth in communities brings urgent demands for infrastructure. Residences that spread into forests and meadows, so each house seems closer to nature than to neighbors, bring particular infrastructural challenges and make services like Internet and fire protection sprawling and costly. Building in forests also increases the risk of wildfire damage to residences. Further, while proximity to public lands, viewsheds, clean air and clear skies raises property values (Cavailhes et al. 2009; Poudyal et al. 2009), long-time residents may face a rising cost of living that outpaces economic growth. In many cases, the local government must step in to respond to these challenges, such as by providing fire protection or subsidizing low-income housing. Local governments may also cover gaps in recreation services when public land agencies, due to budget shortfalls or staffing limitations, lack capacity to respond. For example, rural towns might provide cleaning services for trailhead bathrooms before seasonal federal employees arrive, or may even install those bathrooms in the first place.

The experiences of residents in these Rocky Mountain towns exemplify an evolving relationship between people and public lands. Community stresses often, though not always, create a strong sense of urgency to change that relationship, one of the three preconditions Hanleybrown, Kania and Kramer (2012) deem necessary to launch a collective action. In places where communities also find an influential champion and sufficient financial resources, it is not uncommon to see collective impact efforts emerge. Recreation pressures in Colorado appear to be provoking such action. In just five years in Gunnison County, the county at which Marble sits at the fringe, multiple collectives have formed around natural

resource issues, notably the county-supported Sustainable Tourism and Outdoor Recreation committee, two adaptive management groups working on impacts of timber sales, a working group exploring methane capture at regional coal mines, and a group using collaborative methods to prepare a legislative proposal for new wilderness areas. Each group has members from local advocacy groups, agencies and non-governmental organizations. Expanding recreation, and perhaps the governmental interest in preserving the tax base created by recreation tourism, appears to provoke interest in innovative management approaches. Residents of Marble similarly hope that a new management plan can alleviate recreation conflicts, conserve their distinct history and identity, and restore the lifestyle that initially led them to Marble (Figure 4).

Figure 4. Vehicles congregate beneath the towering columns of marble on the outskirts of town, former site of the Colorado Yule Marble Company's processing mill, the largest in the world when it operated at the start of the 20th century. Photo by Corinne Truesdell.

Planning Responses to Recreation Boom

Public lands have a long history in Colorado and the American West, and the agencies that manage the forests, peaks, and rivers of the Rocky Mountains have worked here for a century. However, the social, political, and economic contexts of natural resource management, as well as the ecological pressures, are changing rapidly. Land management agencies face conflicting missions to both use and conserve public resources, struggle to prioritize directives given from Washington, DC, state, and local leadership, and operate within a powerful national identity built around human rights to access resources. With the expansion of tourism and the new pressures on environmental and social-economic systems, recreation management actions materialize ideals about sustainability and prosperity. Planning processes, such as the Marble working group, matter because they shape the world in which people live. Even the most collaborative planning processes have potential to create injustices or impart harm on people and places.

Current management paradigms in the U.S. understand recreation through Eurocentric lenses: an ecological lens, focusing on how people impact environments by recreating, or a behavioral lens, focusing on experiences and satisfaction of visitors (Frachina, Blahna, and Schlafmann 2019). Consequently, much recreation research centers on existing uses rather than exploring recreation within larger social contexts, ecosystem scales, and nontraditional paradigms. Moreover, people's motivations to recreate have not changed substantially over time, while larger contexts have shifted dramatically, such as the physical climate or new technologies that enable people to access information for trip planning through the Internet or access landscapes using all-terrain vehicles.

The influence of ecological and behavioral thinking on recreation planning has built a context where managers readily seek information for planning processes, but struggle to consider how the planning approach itself shapes the social and environmental outcomes. For example, planning processes are often characterized by a quest for data. The cultural prominence of the scientific method sustains the belief that systematic approaches are necessary to advance knowledge, causing planners to thirst for ever-increasing amounts of data. Data, however, can only supplement a decision-making process. The first step in planning or decision-making must be issue identification and framing, not data collection (Clark and Stankey 2006). Management approaches for framing issues in ways that further recreation and community planning are less studied.

Thus, these emerging working groups seeking to respond to the pressures of expanding recreation in rural communities are left with the question: How can planning, policy, and management cope with rising social and environmental injustice alongside rapid ecological change? New planning paradigms, well suited to these complex landscapes, must take hold to create more equitable and sustainable management models (Blahna et al. 2019). Collaborative and systems-oriented processes have potential to account for the social contexts that weigh as heavily in recreation planning as visitor counts and biological assessments. The remainder of this chapter considers how principles of collaboration and systems thinking

manifest in the formation of the Marble group, along with the particular challenges of attaining the ideals of innovative and responsive management.

Collaboration

In 1990, political economist Elinor Ostrom proposed that including people in conservation rule-making would be vital to creating sustainable socio-environmental systems. Since that time, the value of collaborative planning has been lauded for its adaptiveness and flexibility, for distributing power, and for creating circumstances where stakeholders must take responsibility for their actions. Evidence of the growing social support for collaborative planning process can be found in a growing number of policies that mandate, or at least strongly recommend, community involvement in landscape planning. Most recent public land management planning processes promote collaboration as an effective tool for effecting change on the ground (Charnley, Long and Lake 2014).

The Lead King Loop working group articulated its purpose not to design the plan, but to provide officials with potential strategies for management. Key stakeholders were recruited to the group, including the mayor (also a major business owner) and other town and county representatives, the U.S. Forest Service, business owners and private residents. As with any working group, who is and is not included matters. The Marble group, for example, includes representatives for residents, but not for tourists or other "outsider" groups. What stake do the 17,000 tourists who visit the town each year have in the conversation and how can they claim the opportunity to participate in decision-making processes? Decisions about which groups are invited to send representatives influence the material and social outcomes of the process.

The right to participate in decision-making in Marble is also contested through geographical boundaries (Figure 5). Many residents of the valley live outside the incorporated city boundaries. They do not pay taxes to the town, but are connected to each other and to the issue through social networks and the shared experience of the recreational impacts. Meanwhile, those who live in town affirm their citizenship through the municipality, which forms the foundation for their claim to participate. Part-time residents who geographically qualify still struggle to participate in planning processes and public discussions that take

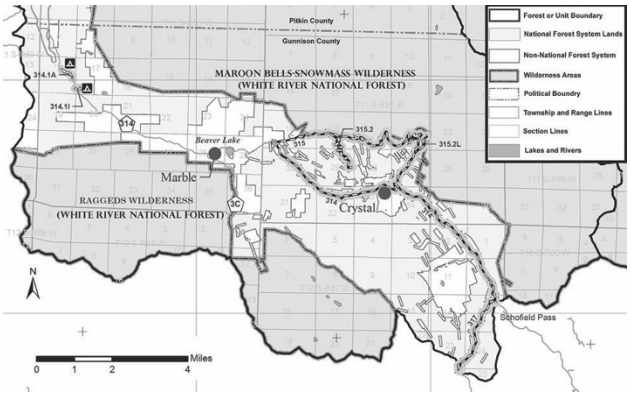

Figure. 5. Lead King Basin Road, towns of Marble and Crystal, White River National Forest. White squares indicate private property holdings outside the municipality. Map is extracted from USFS publication "Summary Motor Vehicle Use Map - White River National Forest", FS-873-0215, dated May 21, 2019.

place when they are not proximate. Many outfitters and tour providers based in nearby communities may also feel their business interests merit representation in the planning process, though they do not reside within the community.

The collaborative process creates insider citizenship, which in turn heightens a sense of belonging. Consider, for example, OHV users whose interests are supposed to be represented by a delegate from a local OHV club. Not only do members of that group attain a sense of belonging through their membership in the club, but they are now included in the decision-making process when their organization takes a seat at the table. On the other hand, an OHV user who is not a member of a club is now an outsider to the planning process, with a diminished sense of belonging. In the working group and other community conversations about Lead King Loop planning, discursive cues also underscore hierarchies of citizenship. Citizens are described as "traditional" or "new wave," typically based on length of residence, part- or full-time residence, and working status, but also referencing their attitude about the future of Marble. In conversation, these perceived categories become shorthand for desired management objectives. "Traditional" residents, often retired or second home owners, are also described as those who favor permitting systems or other tools to restrict access and reduce visitation; "new wave" residents—young, working, and year-round—may be described as favoring tourism growth to support the longevity of the town. Others point to "invisible, silent workers" who commute to jobs outside Marble or work

remotely, and a recent "baby boom" stands to increase the year-round population by about 7% and further underscores the "new wave" view with a reminder that Marble has a future.

The social strata of a small town surfaces quickly, and discussions about recreation management are peppered with tales of cheating spouses, neighbors' misdeeds, and government corruption. Such social networks, however, become the building blocks of governance when collaborative approaches are used. Research has shown that dominant groups persist within collaborations, and that these groups attain power by building strong social networks (Fliervoet et al. 2016). When collaborative processes are promoted as more democratic, even moral (Stringer et al. 2006), there is high potential for power elites to make decisions that appear collaborative. From decisions about who is invited to the table to the social networks that persist even in facilitated groups, collaborative processes continue to hold potential to quiet diverse voices, remake historical injustice, exclude participants, and run the risk of masking those actions through the guise of collaboration. In recreation planning in particular, participants from land management agencies like the Forest Service may struggle with knowing how to act effectively in a collaborative governance, including knowing how to shed the authority they bring to the table through land oversight, historical tradition, enforcement power, access to resources, and even their uniforms.

Systems Thinking

Natural resource managers work within dynamic systems involving social and ecological actions. Complexity is inherent in these systems, which challenge government capacity by demanding integrative thinking. Integrating systems thinking into planning "would explicitly recognize reciprocal connections and relationships between people and the landscapes they occupy" (McCool and Kline 2019, 32). The goal is to understand each element of a system through its relation to other elements, and to understand them as they evolve and adapt over time. Building a planning process using systems thinking, which seeks to understand how changes to one element impact other elements, offers a mechanism to identify and evaluate interventions that have potential to bring change to a system. At a minimum, this approach identifies the key actors and their interactions, and how the providers and users of a recreation experience interact with the recreation landscape and infrastructure (Andereis, Janssen and Ostrom 2004).

Advocates of systems thinking propose the tool as a way to escape "analysis paralysis" where the perceived need to collect vast amounts of data creates an inability to act, and to overcome the mental models that perpetuate "business as usual" because they limit the ability to look forward (Rittel and Webber 1973; Kaufmann et al. 1994). In the natural resource field, influenced by centuries of post-Enlightenment delight in scientifically-generated knowledge, data is abundant and sought-after. Notably, collaboration does not seem to overcome the thirst for data, and in the case of Marble, after just four monthly meetings the group decided it needed more data. The group brainstormed data needs such as vehicle counts, occurrences of misuse, fire danger levels, vegetation impacts, water crossings, and emergency incidents (reported and unreported). Certainly resource limitations constrain the group's ability to attain this data, and systems thinking approaches offer a way to further planning processes by articulating a shared vision.

For unclear reasons, tourism and tourism management are largely perceived to be separate from, or even at odds with, recreation and public lands planning. Perhaps the profit-making aspects are unappealing to those working in public service; perhaps tourism implies large groups who are disconnected from the place, while recreation idealizes small groups and intimate experiences of place. However, tourism thinking holds high potential to push recreation managers into more systems-based approaches, for it emphasizes connections among industry agents as well as the production of nature as a commodity. Moreover, tourism management promotes future-oriented thinking about its own outcomes and objectives, more in line with systems approaches. Increased tourism brings growth in people, but also shifts power bases by bringing tourism entrepreneurs or outside corporations to a community and potentially commoditizing a place and its heritage. Marble residents, for example, look with concern at tour companies based outside the community whose businesses rely upon access to the public land on the Lead King Loop (Figure 6). Their business models and price structures potentially draw business away from Marble-based operators, and those tour groups contribute to the perceived recreational crowding while giving little to the Marble tax base. Systems-thinking approaches can bring the influence of these

Figure 6. Tour groups on the Lead King Basin Trail stop at the Crystal Mill, a powerhouse built in the 1890s to run machinery at nearby silver mines. Some claim it is the most photographed site in Colorado. Photos by Corinne Truesdell (top) and E. Scott Clark (bottom).

outside groups more fully into the socio-ecological system under evaluation.

Conclusion

While many Colorado communities are likely to point to growing numbers of recreation visitors as instigators of change, it is important to recognize that communities themselves bring social and material changes through planning actions. Roads, trails, and parking lots are but one outcome of the recreation mindset now grounded in and inseparable from Colorado's distinctive mountain geography. People's social networks, communities' cultural values, and citizens' sense of belonging all stand to be disrupted through recreation planning. Successful planning may not look like the preservation of an existing way of life, but the creation of tools and systems that can adapt to emerging behaviors. New language for a new paradigm of recreation will take hold, evidence that deep cultural values have shifted. In the town of Marble, planning may ensure the Lead King Loop will offer scenery, adventure, and livelihoods to Marble and its visitors for years to come, but success may more fully be assessed by how the community's identity is shaped by these countless planning actions, like a carver's tools chisel away stone until a sculpture emerges from the marble.

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References

Anderies, J., M. Janssen, and E. Ostrom. 2004. A framework to analyze the robustness of social-ecological systems from an institutional perspective. *Ecology and Society* 9 (1):18.

Blahna, D., J. D. Kline, D. R. Williams, K. Rogers, A. B. Miller, S. McCool, and F. Valenzuela. 2019. Integrating social, ecological, and economic factors in sustainable recreation planning and decision making. In *Igniting the science of recreation: Linking science, policy and action*, ed. S. Selin, 37-46. Portland, OR: U.S. Forest Service, Pacific Northwest Research Station.

Bureau of Economic Analysis. 2019. Outdoor recreation satellite account, U.S. and prototype for states, 2017. Accessed January 15, 2020. https://www.bea.gov/system/files/2019-09/orsa0919_1.pdf.

Cavailhès, J., T. Brossard, J.C. Foltête, M. Hilal, D. Joly, F. P. Tourneux, C. Tritz, and P. Wavresky. 2009. GIS-based hedonic pricing of landscape.

Environmental Resource Economics 44:571-590.

Charnley, S., J. Long, and F. Lake. 2014. Collaboration in national forest management. In Science synthesis to support socioecological resilience in the Sierra Nevada and southern Cascade Range, Gen. Tech. Rep. PSW-GTR-247, ed J. W. Long, L. Quinn-Davidson, and C. N. Skinner, 663-704. Albany, CA: U.S. Forest Service, Pacific Southwest Research Station.

Clark, R.N., and G. H. Stankey. 2006. Integrated research in natural resources: The key role of problem framing. General Technical Report, PNW-GTR-678. Portland, OR: U.S. Forest Service, Pacific Northwest Research Station.

Fliervoet, J., G. Geerling, E. Mostert, and A. Smits. 2016. Analyzing collaborative governance through social network analysis: A case study of river management along the Waal River in The Netherlands. *Environmental Management* 57: 355-367.

Franchina, R., D. Blahna, and M. Schlafmann. 2019. Understanding and fostering connections among people, nature, and public lands. Accessed January 15, 2020. https://drive.google.com/file/d/124qFnt_L4TY0Ugknv7NFogOD2Q8X0Du3/view.

Hanleybrown, F., J. Kania, and M. Kramer. 2012. Channeling change: Making collective impact work. *Stanford Social Innovation Review* 10 (2): 1-9.

Headwaters Economics. 2019. Recreation counties attracting new residents and higher incomes. Accessed January 15, 2020. https://headwaterseconomics.org/wp-content/uploads/recreation-counties-attract-report.pdf.

Henderson, J. R., and K. McDaniel. 2005. Natural amenities and rural employment growth: A sector analysis. *Review of Regional Studies* 35 (1): 80-96.

Kaufmann, M. R., R. T. Graham, D. A. Boyce Jr., W. H. Moir, L. Perry, R. T. Reynolds, and P. S. Corn. 1994. An ecological basis for ecosystem management. U.S. Forest Service General Technical Report RM-246.

McCool, S., and J. D. Kline. 2019. A systems thinking approach for thinking and reflecting on sustainable recreation on public lands in an era of complexity, uncertainty, and change. In *Igniting the science of recreation: Linking science, policy and action*, ed. S. Selin, 37-46. Portland, OR: U.S. Forest Service, Pacific Northwest Research Station.

Ostrom, E. 2009. A general framework for analyzing sustainability of social-ecological systems. *Science* 325:419-422.

Poudyal, N. C., D. G. Hodges, J. Fenderson, and W. Tarkington. 2009. Realizing the economic value of a forested landscape in a viewshed. *Southern Journal of Applied Forestry* 34 (2):72-78.

Rittel, H. W., and M. M. Webber. 1973. Dilemmas in a general theory of planning. *Policy Sciences* 4 (2):155-169.

Stringer L. C., A. J. Dougill, E. Fraser, K. Hubacek, C. Prell, and M. S. Reed. 2006. Unpacking "participation" in the adaptive management of social–ecological systems: a critical review. *Ecology and Society* 11 (2):39.

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LITERARY FIELD GUIDES AND POETIC INVENTORIES IN THE EXTENDED ROCKY MOUNTAIN REGION

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In his poem "Turkey Vulture," John Calderazzo (2013) imagines turkey vultures feasting on the remains of dead trees rather than on carcasses of dead animals. The trees in the poem are lodgepole pines, one of the species of pines that has been hit especially hard by the bark beetle epidemic (Negrón and Cain 2019) in Colorado and the Rocky Mountain West. Each of the poem's seven stanzas (see the full poem in Figure 1) is framed as a question that shows a poetic awareness of the devastation to western forests by bark beetles. The poem doesn't shy away from a calamitous tone, in which "…the rising heat / of a spring morning that's confused itself with mid-summer / or a mid-summer day camouflaged as fire / on the porticos of Hell," demonstrates and alludes to the intertwining and feedback of bark beetle eruptions and climate change. These turkey vultures, rather than cleaning roadkill off the highways, have "skimmed the spine of the Rockies" above the "carrion forests." In the final short stanza of the poem, Calderazzo asks, "What would the sky look like, / roiling with heat and such ravening hunger?" This striking image of a sky filled with vultures draws the reader's attention up—not as a turning away from the Earth, but as an extension of the "ghost forests" below.

Calderazzo's poem is part of *A Poetic Inventory of Rocky Mountain National Park* (Malone 2013), a book that gathered poets and writers' responses to species who live in Rocky Mountain National Park (RMNP) in conjunction with the 2012 BioBlitz at RMNP. The book includes 61 poems and short prose pieces in sections addressing birds; mammals; reptiles, amphibians and fish; and vascular plants, and is an example of a growing number of literary field guides and poetic inventories that gather regional literary responses to specific socioecological communities or bioregions. The Rocky Mountain inventory built upon the format of a project at Saguaro National Park that I designed the year before. Related projects have addressed specific national parks or monuments, such as the 2019 "A Literary Inventory of Organ Mountains-Desert Peaks" (Magrane 2019b),

Cathartes aura
Turkey Vulture
John Calderazzo

What if vultures ate dead trees
instead of dead animals?

What if they learned to feast
on beetle-killed pines?

What if they took their nourishment
from the new ghost forests of Colorado,
the miles and miles of browned out lodgepoles,
the sweeping dust-dry slopes and valleys
of the standing dead?

What if, powered by the rising heat
of a spring morning that's confused itself with mid-summer,
or a mid-summer day camouflaged as fire
on the porticos of Hell,
they opened their six-foot wings
and flapped a few times and lifted blackly from roosts
along the Poudre River, or above the Big Thompson,
or out on the wind-stiffened hissing grasslands
a time zone to the east?

What if, by the thousands, they caught
elevators of expanding air, as they tend to,
and in the death-inflected double helix of those thermals
they gathered above Cub Lake, slowing turning,
swiveling the featherless red heads
that inspired their names?

What if they skimmed the spine of the Rockies
and ignored the scent of a rotting ground squirrel
a mile distant, or a starved elk barely covered by snow,
and, instead of diving for food, they simply hung in the air
like torn shreds of night
above the carrion forests?

What would the sky look like,
Roiling with heat and such ravening hunger?

Figure 1. From *A Poetic Inventory of Rocky Mountain National Park.* Reprinted with permission of the author.

while others turn to addressing bioregions in the form of a literary field guide, blending the genres of literary anthology and field guide, such as *The Sonoran Desert: A Literary Field Guide* (Magrane and Cokinos 2016) and *A Literary Field Guide to Southern Appalachia* (McLarney, Street, and Gaddy 2019). These poetic inventories and literary field guides can be considered community-engaged public geohumanities projects, as they enlist multiple voices to represent, interpret, and (re)imagine human + more-than-human relationships and senses of place (Magrane 2019a). In this short chapter, I briefly focus on three examples from these projects, including two from *A Poetic Inventory of Rocky Mountain National Park* and one from "A Literary Inventory of Organ Mountains-Desert Peaks." While the Organ Mountains-Desert Peaks project extends outside of the southern flank of the Rocky Mountains, into the Chihuahuan Desert, the three species highlighted here all occur within the Rockies.

In her contribution to *A Poetic Inventory of Rocky Mountain National Park*, titled "Bear Grace," Laura Pritchett (2013) writes of climbing into a bear den on a Colorado mountainside (see Figure 2). The first lines of "Bear Grace" pull the reader right in with her: "Bear dens smell good. I know because I've just been graced with the opportunity to be in one, face up against a bear" (95). After this opening, one can't help but be quickly drawn into reading further to find out how this encounter came about. Pritchett goes on to explain how she arrived in the winter dwelling place of the bear, narrating her experience joining bear researchers who had hiked up to the hibernating bears to remove GPS collars. After the researchers had tranquilized the bears and "gently pulled the sow out," Pritchett asked if she could climb in with the younger bear. In her short reflection on the encounter, she blends narration of the experience, "sandwiched between two good-smelling *Ursus americanus*" (96), with reflection on human-bear relationships. She notes that 1/3 of bear deaths in Colorado are connected with human-bear conflicts, and briefly reflects on the "grizzlies that once roamed here, and their sad and purposeful extinction." "Bear Grace" is able, however, to refrain from any sense of didacticism in arguing for empathy for bears. The moment of expository reflection on bear mortality due to human presence is surrounded by the evocative description of this writer's specific embodied and sensory experience of encounter in the bear den, and it's this story itself that carries the day.

This sense of empathy for other species arises in many of the contributions to the growing number of poetic inventories and literary field guides. However, it is far from the only tack that writers take. Some write about the difficulty in really knowing and understanding other species through human perception. For example, in his prose contribution to "A Literary Inventory of Organ Mountains-Desert Peaks" addressing the mountain lion, titled "El Puma and his Tocayos," (see Figure 3), Spencer R. Herrera narrates a hike to Baylor Canyon Pass in the Organ Mountains of southern New Mexico in search of a mountain lion. At one point, all the birds go silent, and Herrera imagines hearing the mountain lion: "It was in that eerie quiet when I thought I heard you. A brittle branch snaps from the boulders behind me, prompting my animal instinct to hunker down and grab my walking stick. But you did not descend down the narrow mountain path." Herrera bookends his search for the mountain lion with a reflection on the big cat's many common names, asking, "how can you have so many names, yet so few people know you?"

The examples of the turkey vulture, bear, and puma that I have discussed and that are re-printed here address charismatic species—or if arguably not charismatic, at least iconic, in the case of the turkey vulture. The multivocal forms of these poetic inventories and literary field guides, which, as I noted above have now gathered writers in a number of locales and bioregions, have also instigated many poems and prose to lesser-known species, from plants such as the poisonous death camas to arachnids such as the vinegaroon to amphibians such as the red-spotted toad. As cultural geographers have long argued, places are continually made and re-made in part through literary and artistic representations, and writers and artists of course play a key role in this process. These projects are about getting to know places through paying attention to one's neighbors. Literary field guides and poetic inventories ask their contributors and their readers to (re)consider the more-than-human inhabitants of one's home, of one's region, and extended, of the biosphere at large.

Ursus americanus
Bear Grace

Laura Pritchett

Bear dens smell good. I know because I've just been graced with the opportunity to be in one, face up against a bear. Head-first, flat-on-my-stomach, drenched in sweat, thinking, *isn't it supposed to stink in here?* And *wow, I have never been happier.*

But my happiness was irrelevant. It was bears' well being that was germane, which is why a group of us had just snowshoed up 1200 feet on a mountainside in Colorado—a trip that involved hours of grunting, whispering, cussing the undergrowth, falling through rotten snow. On this trip were several researchers and vets, all carrying backpacks laden with heavy equipment—tranquillizer guns, avalanche shovels, antenna for receiving signals. They'd located this den with two hibernating bears—a sow and her yearling—for one basic reason: to cut off the GPS collar on the sow, but in a larger sense, to conclude a study that will ultimately help bears stay wild.

I wanted to be there to see it; I wanted to crawl in a den.

The den, once located, was fantastically tiny—a small rock outcropping on a steep hillside. I stomped my feet to stay warm while the researchers dug out the den, tranquilized the two bears, gently pulled the sow out. Since there wasn't room for both bears on the steep ledge, the yearling was left inside.

Could I crawl in?

Sure, they said.

And so, on my stomach, I inched myself forward through brush and rock until I found myself lying with the mother bear behind me and the yearling in front of me—sandwiched between two good-smelling *Ursus americanus*. I breathed in. Vowed to remember this moment. Reached out and put my hand into the yearling's fur, put hand against paw. I couldn't see much of anything—it was too dark—and so I closed my eyes and just felt.

And I made a wish: May we humans get our act together. Bear-human conflicts account for about 1/3 of all bear deaths in this state. The vast majority of these deaths are easily preventable, and mainly have to do with taking care of our trash and crap. I thought of the grizzlies that once roamed here, and their sad and purposeful extinction, and I made a wish that perhaps we humans had grown a bit wiser.

After I inched out, backwards, and could see once more, I studied the sow that was outside—her feet pads (so soft) and teeth (so yellow) and fur (so surprisingly thick). I also watched as her radio collar was cut off. She seemed a little freer, a little more wild.

The tranquilizer was due to wear off and as the humans hurried to finish up, the bears were given eye ointment and a shot of antibiotics and weights were taken. Then, with great care, the bear was put back into her den, next to her yearling, the opening was covered, and the bears left in solitude once more.

As we quietly picked up our gear and prepared to leave, I regarded the bear claw marks on the aspen trees—arcs of five scratches in beautiful patterns, healed over by the tree. One simple enormous hope rose within me: that we humans can mark our homes with such grace and beauty.

Figure 2. From *A Poetic Inventory of Rocky Mountain National Park.* Reprinted with permission of the author.

Puma concolor
Mountain lion

Spencer R. Herrera

El Puma and his *Tocayos*

Puma
Cougar
Mountain Lion
Panther
Catamount

I went looking for you today in all your different incarnations and I all heard was the wind and a few songbirds. The birds were nestled somewhere amongst the tall yucca stalks. If I can hear them pass the *mitote* from one hedgerow to another then I can safely assume you're not around. With my legs feeling tired, yet my spirit rejuvenated after a brisk hike into the thicket of Baylor Canyon Pass, I sit down against a rock face shielding me from canyon gusts and contemplate my mercurial world while I sit peacefully in yours.

The coolness in the shadows provides a sweet respite at this altitude. A fresh monsoon shower allows you and your prey to extend their range in moderate comfort. The small puddles of water that have collected in rock crevices invite other mountain inhabitants to enjoy the fresh rain. You stalk them from almost any vantage point, peering out from a cliff above or hiding in the shadows of a tree line. I wonder if you can smell my presence from a distance while a breeze passes over me and carries my scent through the ravine below.

My imagination runs wild with the possibilities of your existence. And then, as if instructed by some invisible conductor in the wilderness, my avian lookouts cease communication. It was in that eerie quiet when I thought I heard you. A brittle branch snaps from the boulders behind me, prompting my animal instinct to hunker down and grab my walking stick. But you did not descend down the narrow mountain path. It was only the wind blowing through the creosote bushes and the leaves of the mountain oak. But then why did the birds stop singing? Perhaps they took their song where no one could interrupt their afternoon *chisme*. Or maybe they were disappointed that you did not make a dramatic entrance after their crescendo.

I know you're here. Did you see me lean forward and squint my eyes trying to make out the contours of your camouflaged position? Was that you lying in the high branches of the mesquite tree near the cave entrance? Maybe next time you will feel like greeting your neighbors. Sabbaths are meant for rest, after all. Still, I ask, how can you have so many names, yet so few people know you?

Puma
Cougar
Mountain Lion
Panther
Catamount

I went looking for you today in all your different incarnations and I all saw or heard was the wind and a few songbirds.

Notes: *Tocayo* is Spanish for namesake. People with the same name will call each other that. *Mitote* and *chisme* both mean gossip in Spanish. However, *mitote* is used more in the northern New Mexico and southern Colorado Spanish dialect and *chisme* in southern New Mexico and Mexico.

Figure 3. From "A Literary Inventory of Organ Mountain-Desert Peaks" reprinted with permission of the author.

References

Calderazzo, J. 2013. Turkey Vulture. In *A poetic inventory of Rocky Mountain National Park*, ed. C. Malone, 24-25. Fort Collins, CO: Wolverine Farm Publishing.

Herrera, S. 2019. El Puma and his Tocayos. In A literary inventory of Organ Mountains-Desert Peaks National Monument, ed. E. Magrane. *Spiral Orb*, 15. Accessed January 10, 2020. http://www.spiralorb.net/fifteen/herrera.html.

Magrane, E., and Cokinos, C (eds). 2016. *The Sonoran Desert: A literary field guide*. Tucson, AZ: University of Arizona Press.

Magrane, E. 2019a. Applying the Geohumanities. *International Journal of Applied Geospatial Research (IJAGR)* 10 (2):27-38.

———. 2019b. A literary inventory of Organ Mountains-Desert Peaks National Monument. *Spiral Orb*, 15. Accessed January 10, 2020. http://www.spiralorb.net/omdp.html.

Malone, C. (ed.). 2013 *A poetic inventory of Rocky Mountain National Park*. Fort Collins, CO: Wolverine Farm Publishing.

McLarney, R., Street, L.G. and Gaddy, L.L. eds. 2019. *A Literary Field Guide to Southern Appalachia*. Athens, GA: University of Georgia Press.

Negrón, J. F., & Cain, B. 2018. Mountain pine beetle in Colorado: A story of changing forests. *Journal of Forestry*, *117* (2):144-151.

Pritchett, L. 2013. Bear Grace. In *A poetic inventory of Rocky Mountain National Park*, ed. C. Malone, 24-25. Fort Collins, CO: Wolverine Farm Publishing.

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HUMAN-ENVIRONMENT INTERACTION IN THE ROCKY MOUNTAIN WEST

Bannack Ghost Town (1860s mining camp), Bannack, Montana. Photo by Mike Goad.

COLORFUL COLORADO: CONTAMINATION, CONSERVATION, AND MILITARIZATION

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Introduction

The Colorado Tourism Office offers a wintery mountain scene on its January 2020 home page, featuring three intrepid snowshoers and the tagline, "Come to Life: Colorado" (www.colorado.com/). The image fits perfectly the state's reputation for outdoor recreation and active living. The vitality of the tagline—resurrect yourself in Colorado!—inspires recreational visions that intersect cleanly with some of the state's major tourist attractions: skiing, river rafting, fly fishing, mountain climbing, or visiting scenic national parks.

Much as tourism officials would like to cultivate these ideas of Colorful Colorado as a healthy, outdoorsy, or natural state,[1] this of course is not the only way to cast Colorado. Tucked well away from the quavering allure of John Denver's "Rocky Mountain High," Colorado quietly resonates with sites of military extraction, production, training, and disposal that, in sum, make it one of the most extensively militarized states in the U.S. From uranium mines in the southwest that fed the Manhattan Project to Minuteman III missiles tucked in silos in the northeast plains, these militarized landscapes effectively span the state. The character of Colorado's military influence is distinctive in that it may be the only state during the past sixty years to host the complete lifecycle of industrial militarization: from mining and milling weapons-grade ore to weapons production and deployment to military training, command, and finally, weapons dismantling and disposal. While the recreation and outdoor amenities of Colorado are prominently displayed—a mountain silhouette remains etched on every Colorado license plate—you will need to search to find many signs of Colorado's full-spectrum militarization. In recent decades, these two characteristics of the state have become ever more intertwined as a number of aging militarized sites have been redesignated to recreation or conservation purposes.

Colorado's comprehensive contribution to U.S. militarization is often lost amid the scenery, but this integration of military production and output has in many ways shaped the state's historical development more profoundly than the recreational or environmental attributes featured on websites, magazines, or movies. In this chapter, I examine the dual production of nature and national defense by focusing on three particular places: the former chemical weapons facility at the Rocky Mountain Arsenal, just outside of Denver; the Rocky Flats Plant, which for nearly four decades manufactured plutonium triggers for America's nuclear arsenal; and the aerospace command center buried inside Cheyenne Mountain, near Colorado Springs (Figure 1). Each of these places today is enveloped by a federal or state conservation area, and increasingly the qualities for which they are known center around conserving nature rather than military production. If we are to truly understand Colorado, we must attend not just to the frequent depictions of recreation or the outdoors that boosters promote, but also to the creation, contamination, and conversion of its militarized landscapes.

From Bombs to Bald Eagles

As the Second World War raged across parts of Europe, Asia, and the Pacific, the U.S. committed itself in earnest to a chemical weapons program. The question of manufacturing remained unsettled: where best to locate a large chemical weapons plant? The ideal site would need access to transportation networks such as highways, railroads, and an airport, yet be far enough inland to stymie long-distance bombers from Germany or Japan. It needed to be large enough to accommodate chemical production facilities, while also accommodating a buffer of land around its perimeter. Access to gas, water, and electricity was essential, along with a ready source of labor, yet the site also needed to be remote enough from population centers to limit exposure in case of accidents. To afford protracted storage, a stable geology with a dry climate was important. And finally, the land needed to be inexpensive enough—politically and financially—to allow rapid transfer to federal ownership

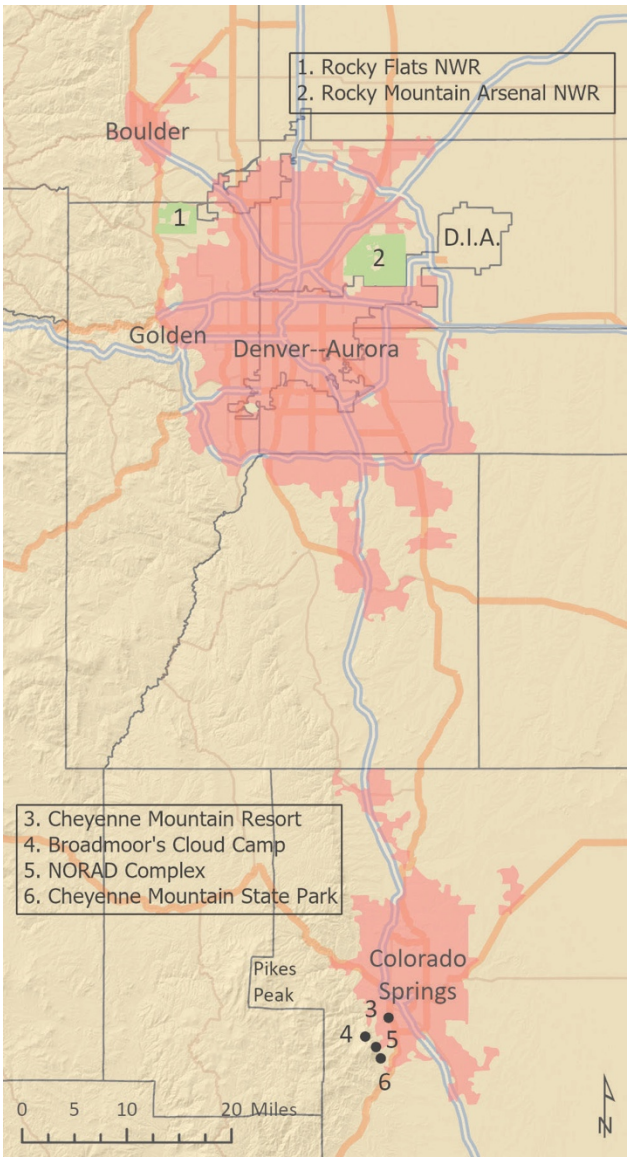

Figure 1. Locator map of Colorado Front Range. Cartography by Matt Gottfried.

(Hoffecker 2001; *Eagle Watch* 1992). Fifteen kilometers northeast of Colorado's state capitol building, the Army found just the place.

In May 1942, the U.S. Army committed some 8,000 ha of land to the project. As the nation plunged into the war effort, more than two hundred farm families north of Denver were given just a few weeks' notice of eviction as their land was condemned (*Eagle Watch* 1992; Hoffecker 2001; FWS 1999). Before the last families had finished packing or harvesting early summer crops, the Army moved crews on site to build what would become the Rocky Mountain Arsenal.

For the next four decades, the facility produced a smorgasbord of deadly chemical and nerve agents.[2] Lewisite, known as the "Dew of Death," mustard gas, and chlorine gas were but the first course in what would prove to be a long menu of weapons and other compounds manufactured, cached, or dismantled at the Arsenal (Figure 2). By the time it finished its forty-year run, the Arsenal's products included napalm, sarin and VX nerve agent, white phosphorus grenades, TX wheat rust pathogen, rice blast spores, the rocket fuels hydrazine and Aerozine 50, and a vast assortment of button bombs, cluster bombs, and other explosives (Rocky Mountain Arsenal Federal Facilities Agreement 1989; Hoffecker 2001).

Figure 2. Rocky Mountain Arsenal Chemical Weapons Plant, 1970s (Clayton B. Fraser, Fraserdesign, Courtesy of Library of Congress, Prints and Photographs Division, Washington, D.C.).

By the 1960s, local farmers reported their livestock falling ill; that same decade, Denver experienced a series of unusually strong earthquakes, which were subsequently linked to the deep-well injection of chemical wastes from the Arsenal (*Denver Post* 1965; Larsen 1966). In the 1970s, the area of the Arsenal's open-air Basin F chemical waste pit was labeled the most contaminated 2.5 km^2 (square mile) on earth (e.g. Westing 2008). In 1982, amid increasing concerns of groundwater contamination and a growing call to ban chemical weapons, the Rocky Mountain Arsenal ceased operations. In 1992, Congress designated the site a national wildlife refuge, which now spans more than 6,000 ha immediately west of Denver International Airport.

A tour of the site today stirs little memory of the history of weapons production and environmental contamination generated by decades of military activity. Although the visitor center includes exhibits documenting the eviction of local farmers, the production of chemical weapons and commercial pesticides, and the subsequent contamination, closure, and $2 billion cleanup of the Superfund site, the featured attractions of the Rocky Mountain Arsenal now largely center on wildlife and habitat conservation (Figure 3).

Figure 3. Rocky Mountain Arsenal National Wildlife Refuge, 2015. Photo by author.

A reproducing herd of bison roams across much of the refuge, bald eagles roost among cottonwoods along First Creek, coyotes and mule deer dash across open fields, and thousands of prairie dogs churn the soil, creating habitat in turn for burrowing owls, badgers, rattlesnakes, and the refuge's most recent (and imperiled) addition, black-footed ferrets. Refuge officials estimate that the Rocky Mountain Arsenal National Wildlife Refuge now receives some 300,000 visitors annually, almost none of whom likely arrive thinking about weapons of mass destruction or the toll of Colorado's chemical contribution to the U.S. weapons stockpile (see Havlick, Hourdequin, and John 2014).

Plutonium Paradise

A drive south along the Front Range from Boulder to Golden takes travelers past several tracts of protected open space, popular with hikers and mountain bikers, and the newly-opened Rocky Flats National Wildlife Refuge. Though open space, wildlife, recreation, and growing suburban development stand out as primary uses of this land today, from 1952 to 1989 the tallgrass prairie of this stretch served as a central node of the United States' nuclear weapons production. Just 12 km south of Boulder and bordering Denver's western suburbs, the Department of Energy's Rocky Flats Plant manufactured approximately 70,000 plutonium "pits," the core triggering devices in nearly every weapon in America's nuclear arsenal (e.g. CDPHE 1999; Krupar 2013; Grenoble 2017; Calhoun 2018; Havlick 2019).

Production at the 2,500-ha site stopped in 1992, following an FBI raid on the facility three years earlier. In 2001, Congress passed a bill authorizing Rocky Flats National Wildlife Refuge, providing the land could be cleaned to meet state and federal health standards (U.S. Fish and Wildlife Service 2005). Six years and $7 billion of remediation later, in 2007 state and federal regulators deemed the site clean enough and the wild-life refuge was officially established across 80% of the grounds; the core production areas in the center of the tract remain under the custody of the U.S. Department of Energy. In September 2018, despite local opposition and legal challenges, the new wildlife refuge opened to public use and recreation.

The active production period of the Rocky Flats plant was marked not only by its weapons manufacturing, but also by controversy and protest. In addition to plutonium, hazardous materials used at the facility included uranium, beryllium, tritium, and carbon tetrachloride. The degree of contamination caused by these components remained largely hidden during Rocky Flats' production period, but the plant was the focus of persistent anti-nuclear activism in the 1970s and '80s. Controversy and protest surrounded the plant, at times literally. In the fall of 1983, tens of thousands of protestors joined hands to surround the site in a daylong protest (Dodge 2013).

The Rocky Flats plant was also the site of numerous accidents and safety violations. Major fires broke out in one of the main plutonium operation centers in 1957 and 1969, releasing plumes of radiation across the Denver metro area (e.g. Grenoble 2017). Whistleblowers eventually alerted environmental regulators, and in 1989 the U.S. Federal Bureau of Investigation (FBI) led a raid on the plant (Grenoble 2017). The ensuing investigation documented safety violations and environmental contamination at Rocky Flats, including more than two hundred fires, serious injuries to workers, and careless disposal of hazardous waste. The facility was added to the United States'

Superfund list of most contaminated sites in 1989. By the time the plant closed in 1992, one of its structures, Building 771, was deemed the most dangerous building in the United States due to radiation levels in its "infinity room" that ran clear off the charts (ABC News 1994).

Although the conditions at Rocky Flats remain too hazardous to accommodate commercial or residential uses on-site (the cleanup was pegged to a safety standard for a refuge worker spending no more than forty hours per week at the facility), lands bordering the wildlife preserve have been developed for new suburban residents. Marketing materials tout the open space amenities of the Rocky Flats refuge. Language pitching the new Candelas development on the south edge of Rocky Flats nearly matches the State of Colorado's own tourism materials, invoking the good life pursued outdoors: "There is a magnificent sweep of mountain pastureland you'd swear you've seen before on picture postcards of the great American West. This wide-open landscape, this epitome of raw western beauty... presents a life full of the very things people love most about Colorado. Come live life wide open" (Candelas 2018).

Both the developers and the wildlife managers emphasize the fact that a multi-billion dollar restoration effort led to the site's certification as clean and ready for public use. Critics, meanwhile, raise concerns that regulators required just the top two meters of the site to be treated and tested for plutonium hazards; deeper than that, there are no limits on the radioactive material allowed to remain in place. The new refuge lands provide a chance to protect habitat across diverse settings, including xeric grasslands and riparian corridors that have become scarce amid Front Range sprawl. Much like other sites of military-to-wildlife transition in the U.S. and internationally, Rocky Flats presents ecological opportunities that are both real and fraught with complexity (e.g. see Havlick 2011; 2018; 2019). Even as these changing land uses offer new conservation possibilities, they also challenge us to examine how restoration activities can pursue conservation goals without obscuring the important meanings, memories, and cultural attributes (including hazards) that make places such as Rocky Flats distinctive *and* problematic.

Resorts, Recreation, and Aerospace Command

If Pikes Peak is "America's Mountain," as Colorado Springs boosters like to say, then nearby Cheyenne Mountain deserves to be considered America's Atomic Peak. Tucked deep inside the granite heart of Cheyenne Mountain sits the nuclear command center for the United States' Cold War defense infrastructure. For approximately fifty years, the North American Aerospace Defense Command (NORAD) ran its daily operations from the Cheyenne Mountain complex, serving as an essential node of surveillance, command, and control for the U.S. nuclear arsenal (Figure 4). Shifting budgetary and strategic needs moved much of NORAD's activity to nearby Peterson Air Force Base in 2006, but a communications and operations center remains on-call within the hollowed-out core of Cheyenne Mountain.

Figure 4. NORAD entrance (https://www.norad.mil).

Cold War design specifications for the NORAD complex dictated a self-contained underground command facility capable of withstanding multi-megaton nuclear impacts and continued operations for an indefinite period of time. Excavation began in May 1961, and after three years and nearly 700,000 tons of rock had been hauled out of the mountain, the new NORAD facility was complete within its granite mantle. The command center's underground complex includes six million gallons of water storage, 1.9×10^6 ltr (500,000 gallons) of diesel fuel, a ten-megawatt power plant, and buildings constructed on shock-absorbing springs designed to allow life to continue uninterrupted for weeks inside the mountain (Scoles 2017; NORAD 2013). Built less obviously into the plan was the fact that NORAD employees headed underground every day with the knowledge that in the event of a full-scale nuclear attack, they would be sheltered in their massive granite bunker while their families, friends, and hundreds of thousands of Colorado Springs residents suffered the consequences above-ground.[3]

If you visit Cheyenne Mountain today, you will be greeted not with the face of nuclear catastrophe but with an array of recreational and commercial attractions. If you come here looking for traces of Cold War Armageddon, what you are more likely to find instead is posh resorts and mountain bicycling trails.[4] At the base of the mountain, the Cheyenne Mountain Resort —"Where Luxury Meets Breathtaking"—offers an Olympic-sized pool, fishing pond, championship golf course, full-service spa, and fine dining (https://www.cheyennemountain.com/).

Higher up, the five-star Broadmoor Hotel's Cloud Camp Resort is perched atop the north summit of Cheyenne Mountain, accessed by guests via mule-back, by hiking several miles up the peak, or jostling inside an SUV up a twisting dirt road. Cloud Camp bills itself as an "authentic Colorado escape," featuring panoramic views for those bold enough to participate in this all-inclusive "Wilderness Experience" (Cloud Camp 2018). Visitors to Cloud Camp enjoy tastefully appointed log cabins, ziplines, hot tubs, archery, and cooking classes with premium chefs working to prepare their daily meals (personal communication 2019). The camp is a modern update on the original Cheyenne Mountain Lodge, which opened in 1926 and offered visitors access via elephant-back on today's mule and SUV route (Saint 2002).

Nine hundred fifteen meters (3000 feet) below Cloud Camp, the more modest Cheyenne Mountain State Park offers its own array of recreational experiences, with 40 km of hiking and mountain bicycling trails, a campground, nature trails, annual running and mountain bicycle races, and picnic areas. Colorado touts the park as a place where, "you can explore nature's diversity with prairie-to-peak ecosystems" (Colorado Parks and Wildlife 2018). A recently-constructed trail also gives visitors the option to hike to Cheyenne Mountain's 2,985 m (9,500 feet) south summit. The major debate that surfaced around this new trail had nothing to do with militarization or security, but focused instead on whether mountain bikes would be permitted past the ridgeline onto the rocky summit trail.

Military Legacies

A casual look at Colorado and its recent military footprint presents a middling state in terms of defense expenditures and jobs. Estimates in 2015 found direct defense spending statewide of $8.7 billion, with a total output of $27 billion from Department of Defense-related economic activity. These revenues supported approximately 170,000 jobs, or a little more than five percent of the state's total (Military's Impact on State Economies 2018). When viewed from a longer historical perspective, however, at key points in the growth of some of Colorado's most important cities—Denver, Boulder, and Colorado Springs—military projects served as important catalysts of growth, employment, research funds, and industrial development. The fact that major sites in this development—the Rocky Mountain Arsenal, Rocky Flats Plant, and Cheyenne Mountain—have now been decommissioned or overlain with a new conservation purpose reflects a shift in Colorado's economic orientation and popular appeal, but also serves to obscure the legacies of displacement, control, and contamination that in many ways characterized these militarized landscapes.

Colorado's comprehensive contribution to U.S. military development is often lost amid the scenery. At one level this might seem an inspiring storyline: that the impacts of twentieth century war efforts can fade to the background and be supplanted by a resurgent nature, or a rededication by Coloradoans to restore damaged and degraded landscapes. On this view, the Colorado Tourism Office's slogan can be reimagined as a landscape exhortation: Come to Life, Colorado! But the normalization of Colorado as simply a beautiful state can also serve to override other qualities that ought to keep our attention. After all, the military build-up of the state isn't just a story of the past, but in many ways remains a story that impacts Colorado today and into the future.

How many visitors to today's Rocky Mountain Arsenal National Wildlife Refuge, for example, recognize that the groundwater flowing from the former chemical weapons plant still seeps with toxic chemicals dumped at the site more than thirty years ago? Buried clay barriers and massive pumps dotting the perimeter of the refuge lands seek to contain and clean the underground plume long-term, but this invisible chemical stew points to the mixed qualities of this place, which has produced deadly weapons and an urban nature attraction.

At Rocky Flats, plutonium remains on-site in unknown quantities, buried beneath a requisite two meters of soil, but vulnerable to wind, erosion, biotic transport, and human disturbances that will demand the vigilance of health officials for the better part of the element's 24,000-year half-life. With new suburbs and development converging each year on the

site of the former nuclear weapons facility, it seems likely that headlines like those from August 2019 will become only more common: "Elevated Plutonium Levels Found Near Old Rocky Flats Plant" (Zellenger 2019).

And Cheyenne Mountain, with its hidden command center, remains on standby, reminding us that the threat of thermonuclear war may for the moment be lost from view, but mustn't be forgotten. After all, we need to drive just a few hours to the open plains of northeastern Colorado to encounter clusters of embedded missile silos, primed for launch and armed with the very weapons that workers at the Rocky Flats Plant almost surely helped to make. The Colorado of the present is in many ways also the Colorado of the past, and this past is replete with the development, danger, and debris of a thorough commitment to militarization.

Notes

1. Demographic and activity data indicate that Colorado's population *is* among the most active, lean, and physically fit in the United States (e.g. Stoller 2019; Walker 2016).
2. For a portion of this time, the site was also leased to industrial chemical manufacturers such as Shell Chemical Corporation.
3. This is a point related clearly by Sarah Scoles in her May 3 article in *Wired*.
4. The entrance road and portal to the NORAD facility remain visible not far above the campground of Cheyenne Mountain State Park.

References

ABC News. 1994. Nightline: the most dangerous building in America. Accessed March 20, 2019. https://www.youtube.com/watch?v=ZDMz0RtZYtY.

Calhoun, P. 2018. Focus of Protests Forty Years Ago, Rocky Flats Set to Reopen as Wildlife Refuge," Westword, April 26. Accessed November 5, 2018. https://www.westword.com/news/rocky-flats-national-wildlife-refuge-a-former-nuclear-weapons-plant-opening-summer-2018-10239043.

Candelas. 2018. Candelaslife.com home page. Accessed November 3, 2018. https://www.candelaslife.com/.

[CDPHE] Colorado Department of Public Health and Environment. 1999. Summary of findings: historical public exposure studies on Rocky Flats. Denver: Colorado Department of Public Health and Environment.

Cloud Camp. 2018. The Broadmoor. https://www.broadmoor.com/cloud-camp.

Colorado Parks and Wildlife. 2018. Cheyenne Mountain. Accessed June 18, 2018. http://cpw.state.co.us/placestogo/parks/CheyenneMountain.

Denver Post. 1965. Denver region shaken by 5 recorded quakes. September 30.

Dodge, J. 2013. Peace and Justice Endures. Boulder Weekly, October 10. Accessed October 15, 2018. https://www.boulderweekly.com/news/peace-and-justice-endures/.

Eagle Watch. 1992. Vol. 4 (8). Commerce City, CO: U.S. Army Rocky Mountain Arsenal Public Affairs Office.

[FWS] U.S. Fish and Wildlife Service. 1999. *Rocky Mountain Arsenal National Wildlife Refuge: A place like no other.* U.S. Fish and Wildlife Service. Commerce City, CO: Department of the Interior.

———. 2005. *Rocky Flats National Wildlife Refuge Final Comprehensive Conservation Plan*. Commerce City, CO: Department of the Interior.

Grenoble, R. 2017. Rocky Flats Made Nukes. Then it Made a Mess. Now it's About to Become a Public Park. *Huffington Post*. Accessed September 21, 2018. https://www.huffingtonpost.com/entry/rocky-flats-colorado_us_591c81c5e4b034684b08bc13.

Havlick, D. G. 2018. *Bombs away: militarization, conservation, and ecological restoration*. Chicago: University of Chicago Press.

———. 2011. Disarming nature: converting military lands to wildlife conservation. *The Geographical Review* 101 (2): 183-200.

———. 2019. Confounding restoration: environmental politics and ecology in militarized landscapes. In A *research agenda for military geography,* ed. R. Woodward, 174-190. London: Edward Elgar.

Havlick, D. G., M. Hourdequin, and M. John. 2014. Examining restoration goals at a former military site. *Nature and Culture* 9 (3):288-315.

Hoffecker, J.F. 2001. *Twenty-seven square miles*. Colorado: U.S. Fish and Wildlife Service, Rocky Mountain Arsenal National Wildlife Refuge.

Krupar, S. R. 2013. *Hot spotter's report: military fables of toxic waste*. Minneapolis, MN: University of Minnesota Press.

Larsen, L. 1966. Study supports arsenal well quake theory. *Denver Post*, March 17.

Military's Impact on State Economies. 2018. National Conference of State Legislatures. Accessed January 15, 2020. https://www.ncsl.org/research/military-and-veterans-affairs/ military-s-impact-on-state-economies.aspx.

[NORAD] North American Aerospace Defense Command. 2013. A brief history of NORAD. Accessed January 15, 2020. https://www.norad.mil/Portals/29/Documents/A%20Brief%20History%20of%20NORAD%20(current%20as%20of%20March%202014).pdf.

Rocky Mountain Arsenal Federal Facilities Agreement. 1989. Foster Wheeler Environmental Corporation.

Saint, S. 2002. The Springs' Other Mountain: There's a Lot More to Cheyenne than NORAD. *Colorado Springs Gazette*, January 8.

Scoles, S. 2017. A rare journey into the Cheyenne Mountain complex, A super-bunker that can survive anything. *Wired*, May 3.

Stanley, D. 2016. 13 secrets of NORAD and Cheyenne Mountain. Accessed December 16, 2017. https://www.thedenverchannel.com/lifestyle/discover-colorado/secrets-of-colorado/13-secrets-of-norad-combat-operations-center-and-cheyenne-mountain-air-force-station.

Stoller, G. 2019. 9 States in South are fattest, Utah and Colorado are fittest. *Forbes*, November 12. Accessed January 14, 2020. https://www.forbes.com/sites/garystoller/2019/11/12/9-states-in-south-are-fattest-utah-and-colorado-are-fittest/#4597c1824d90.

Walker, C. 2016. Colorado is nation's least obese, most physically active state. *Westword*, December 19. Accessed January 14, 2020. https://www.westword.com/news/colorado-is-nations-least-obese-most-physically-active-state-8600642.

Westing, A. H. 2008. The impact of war on the environment. In *War and public health*, ed. B. S. Levy and V. W. Sidel, 69–86. 2nd ed. Oxford: Oxford University Press.

Zellenger, M. 2019. Elevated plutonium levels found near old Rocky Flats Plant: How worried should we be?" 9News (Denver), August 19. Accessed September 19, 2019. https://www. 9news.com/article/news/local/next/elevated-plutonium-levels-found-near-old-rocky-flats-plant-how-worried-should-we-be/73-5ebafb20-e7bb-4fac-a45a-4a9c05b5e142.

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COLORADO HEADWATERS AND SUSTAINABILITY IN THE ANTHROPOCENE

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Colorado Headwaters

Around the world, headwater regions face unprecedented challenges as they seek to develop and utilize their water resources. In these regions, catchments produce water that is used successively by many users as it descends downstream toward the oceans. In many parts of the world, "water towers" or mountainous source areas, are tributary to arid and semi-arid zones, which are vulnerable to water scarcity and conflict (Messerli et al. 2004). Headwaters are critical to ecosystem health as areas of biological diversity, altitudinal gradients that support significant ecological niches, and maintenance of the natural discharge regime where flow originates. They are embedded within the socio-economic systems at both the regional and national scale where shared governance is essential to water management across political boundaries.

This paper examines the headwater watersheds located in the state of Colorado (Figure 1). For this discussion, these watersheds are defined by the main rivers that cross the Colorado state border. The nested spatial scale of contributing streams within increasing watershed area reveals the connectivity of water across the landscape. The hydrosocial system provides a framework to reinvigorate a von Humboldtian approach to understanding the complexities of water management in the Anthropocene (Callisto et al. 2019).

Humboldt described the importance of mountains as areas of high diversity due to the compression of multiple climates and terrestrial biomes across an elevational gradient (Korner and Spehn 2019). Anthropogenic "biomes" reveal contemporary, human-altered forms on the landscape (Ellis and Ramankutty 2008)—the outcomes of the hydrosocial system. As terrestrial biomes shift upward in elevation so do anthropogenic biomes concentrating pressure on fragile habitats (Appenzeller 2019; Kelly and Goulden 2008) (Figure 2). The anthropogenic biomes are not only the legacy of past human activity but also

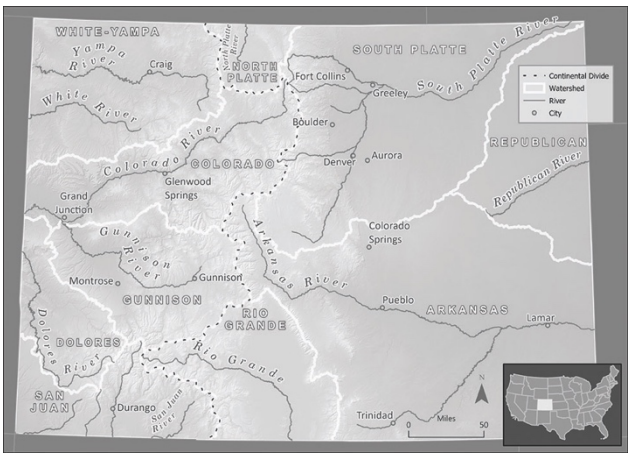

Figure 1. Colorado Watersheds. Cartography by J. Reyling, CSU Geospatial Centroid.

the result of rapidly changing climates and economic transition.

The continental divide of the Rocky Mountains creates a north-south continuum across the state of Colorado. With the highest peaks in central North America, over one hundred of the tallest peaks are located within the state boundaries forming the central water tower of the continent. Colorado is a snowmelt-dominated system where the seasonal snowpack and mountain runoff provides water supply across the U.S. West (Figure 3). Water takes on different roles across the elevational gradient; it has different uses (e.g., agricultural, municipal supply, ecosystem needs) and is bound to different water management sectors (i.e., water supply agreements, water quality regulations, water use requirements).

These watersheds straddle a complex critical gradient that includes the alpine snow accumulation zone essential for water supply, a forested zone that represents a transitional ecological landscape that has been disturbed by large scale wildfires and widespread beetle infestation, and a semi-arid lower elevation zone that has experienced rapid population growth dependent upon a permanent reallocation of water from agricultural to urban uses. Colorado is a

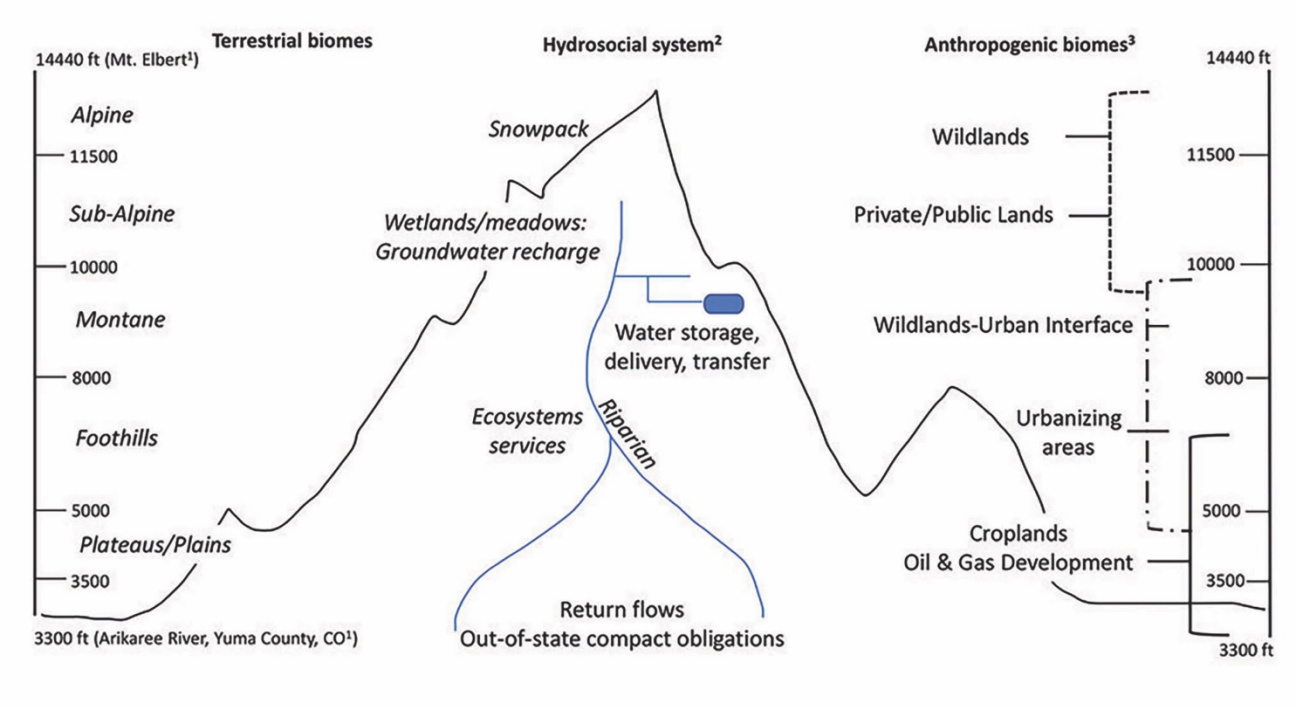

Figure 2. Terrestrial and Anthropogenic biomes of Colorado juxtaposed with the hydrosocial system.
[1]Highest and lowest point in Colorado.
[2]Hydrosocial system demonstrates the connectivity water provides from the headwaters to downstream areas. Snowpack is monitored for water supply for human and ecological requirements. Wetlands/meadows are upstream regions for groundwater recharge and stream base flows; ecosystem services are dependent upon instream flows for fisheries and aquatic health. Water storage, delivery and transfer include infrastructure (reservoirs, ditches, canals) and tunnels for trans-basin water transfers. Downstream users include out-of-state water compact obligations, return flows to rivers, and groundwater management plans.
[3]Anthropogenic biomes of Colorado reflect the human influence across the elevational gradient. Wildlands are composed primarily of federal lands managed as a public commons (national parks and forests). Public and private lands are intermixed across the mountainous headwater region for forestry, ranching, and mining. The wildland-urban interface is an expanding zone where increasing development is occurring in the form of retirement communities, second homes, and recreational activities (i.e., ski resorts). Rapid urbanization is occurring in the plains and foothills of Colorado. Downstream water uses include agriculture, increasing oil and gas development, and out-of-state water compacts to provide water to downstream states.

Figure 3. Extent of watershed with origins in Colorado. Cartography by J. Reyling, CSU Geospatial Centroid.

bellwether in terms of exposure to changing climatic conditions in headwater areas as well as a leader in identifying complex solutions for sustainable solutions and reflects conditions found in mountain regions around the world.

Multiple headwater streams contribute to these watersheds forming major rivers (Figure 4). The Yampa, White, Gunnison, Dolores, and San Juan rivers originate in Colorado (with their own tributary streams) and flow west to the Colorado River, eventually ending at the Gulf of California. The North and South Platte Rivers flow east to the Platte River and join the Missouri. The Republican River originates in eastern Colorado, meets the Kansas River and flows to the Missouri River and beyond to the Mississippi River. The Arkansas River flows to the Mississippi River which discharges into the Gulf of Mexico.

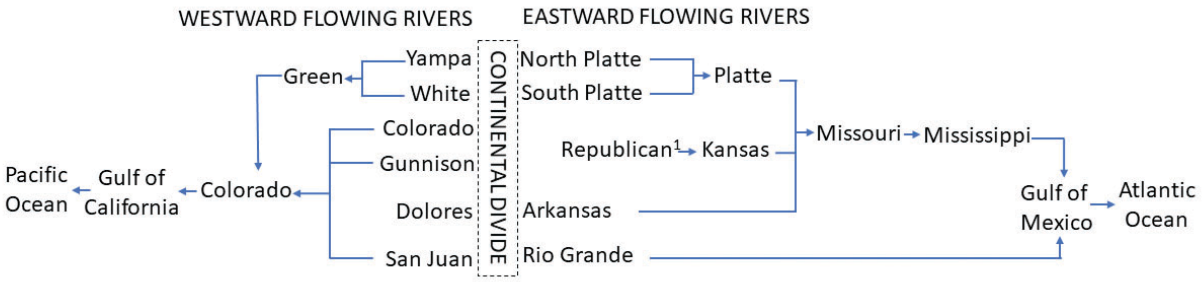

Figure 4. Colorado headwater rivers.
[1]The headwaters of the Republican River are located in the eastern high plains of Colorado. The Republican River is included due to its importance as a transboundary river (Kansas and Nebraska) and surface flow contributing to groundwater recharge to the Ogallala Aquifer.

The Hydrosocial System of Colorado Headwaters

The hydrosocial system of Colorado is complex. Headwater rivers face a common suite of issues associated with water security. The United Nations [UN] defines water security as:

> *sustainable access to adequate quantities of acceptable quality water for sustaining livelihoods, human well-being, and socio-economic development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability.* (UN 2013).

The Colorado hydrosocial systems exemplify the need to develop comprehensive and integrated planning strategies that interlink humans and ecology. This Colorado hydrosocial system is summed up by the fact that approximately 80% of the precipitation falls west of the Continental Divide while 85% of the population and twice the amount of irrigated acres are situated east of that divide (State of Colorado 2015).

Wildlands

The headwaters of Colorado are found in the alpine and sub-alpine biomes of the Rocky Mountains where the annual snowpack provides the basis for the water supply. The wildland biome is made up of predominately public lands supporting essential ecosystem services in the Colorado headwaters that include providing water, regulating local microclimates, supporting nutrient cycles, and recharging groundwater and baseflow of streams (Millennium Ecosystem Assessment 2005). These biomes are representative of the public commons or wildlands where the upper watersheds and forests are owned by federal and state agencies. These federal lands are concentrated in the U.S. Forest Service (FS) (14,483,003 acres), the U.S. National Park Service (NPS) (661,506 acres) and in the Bureau of Land Management (BLM) in the lower elevations (8,313,557 acres) (Vincent et al. 2017). Colorado state lands are approximately 3,243,258 acres (Martinuzzi et al. 2010) made up of state forests and parks.

Public/Private Lands and the Wildland-Urban Interface

Located at lower elevations from the wildland biome is the transitional zone made up of a mixture of public and private lands. This zone is considered transitional for several reasons. Over the past 30 years, Colorado has warmed by approximately 2º F (Lukas 2018). Due to climate change and seasonal fluctuations (Dettinger et al. 2015), multiple infestations of bark beetle have dramatically impacted the forests of Colorado. Since 1996, 3.4 million acres of pine forests have been impacted by mountain pine beetle and 1.78 million acres of Engelmann spruce have been affected by the spruce beetle. These infestations have caused tree mortality in approximately one-fifth of Colorado's forests (Colorado State Forest Service 2017).

The extent of the forest die-off has contributed to increased fire danger across the wildland-urban interface. Combined with warmer temperatures, extended summer seasons, long-term droughts, and the legacy of past forest management, fire occurrence and intensity have significant impact. Although some plants and ecosystems benefit from fire, the increasing frequency and intensity of wildfires have detrimental results (Schoennagel et al. 2017). Local fire impacts include riparian vegetation loss, effects on the

hydrology and stream flows, increased erosion and sedimentation in streams, and impacts on aquatic com-munities, food webs, and processes (e.g., nutrient cycling) (Bixby et al. 2015). Downstream results from fires include increased sedimentation in streams, impacts on water infrastructure facilities, and effects on municipal water supplies (Venable et al. 2017).

In 2018, Colorado experienced the worst fire season on record with five of the largest wildfires burning over 274,000 acres concentrated in the wildland-urban interface (Mitchell 2018). The Wildland-Urban Interface (WUI) is defined as the zone where houses meet or intermingle with undeveloped wildland vegetation (Radeloff et al. 2005). Colorado's WUI extends across 2,335,640 acres in the headwater counties (Martinuzzi et al. 2010). From 2000-2016, Colorado ranked second among U.S. states in percentage of burned area in the WUI where property damage to homes and communities, evacuations and fire-fighting are not only increasing but are more costly to lives and livelihoods (Schoennagel et al. 2017).

Mountain towns located within the transition zone are undergoing demographic change. Seasonal homes, new subdivisions, and retirement communities are drivers of environmental and economic change in Colorado's watersheds in the form of new roads, services, infrastructure, and demands for resources (i.e. water and energy) as well as exposure to risk from fires in the WUI. Four Colorado mountain communities are among the top 15 in the U.S. with the largest increase in the 65-plus population between 2010 and 2016 (Steamboat Springs, Edwards, Breckenridge, Glenwood Springs) (Svaldi 2018). These communities are also evidence of an economic transition where traditional sectors (agriculture and mining) are placed in direct competition with emerging economies based on recreation, tourism, and community services (i.e., medical and health centers).

The legacy of past land use practices is evident in this transitional zone causing other water management issues. Past forestry practices, road and rail construction, mining, and trans-basin water infrastructure altered ecological habitats (Wohl 2001). Scattered throughout the Rocky Mountains are numerous abandoned mining sites where acid mine drainage causes water pollution and contamination downstream (Graves et al. 2017). There are 200 Superfund sites in Colorado. Of the 24 listed on the National Priority List, ten are located in the Colorado head-waters associated with active and inactive mines (Environmental Protection Agency [EPA] 2019).

Urbanizing Areas/Croplands/Oil & Gas Development

The eastern plains and western plateaus of Colorado are experiencing rapid urban growth. From 2010 to 2015, Colorado was the second fastest growing state in the nation with people moving to Front Range communities (World Population Review 2019*)*. These communities are dependent upon water resources from Rocky Mountain snowpack, mountain diversions, and water transport systems. Although agriculture remains the top water consumer in the state (4,717,000 acre feet/year - AFY), growing cities and industry (371,000 AFY) place a demand on water resources, shifting water planning to these needs (Colorado Water Knowledge 2020). Infrastructure projects in the form of new or improved water conveyance and storage facilities are needed for downstream users and growing communities. Innovative approaches to water management are being explored through water banking, alternative transfer methods, and water sharing efforts to reduce the complexity and costs of outright water purchases.

Agriculture is central to Colorado's economy. New farming methods are based on improved technologies, crop varieties adapted to drought, and water conservation. Additional water to meet municipal demand will likely come from irrigated agriculture. Water transfers that permanently remove water from agriculture (i.e., buy and dry) have been undertaken in both the South Platte and Arkansas River basins (Parmer et al. 2018). A key component of Colorado water law and a key aspect of the hydrosocial cycle is the relationship between water rights, return flows, and water use. Water use produces ground and surface water return flow needed for downstream water rights holders, instream flows, and water delivery for interstate compacts (Water Education Colorado 2015). The eastern plains have experienced serious overdrafts of groundwater and over-appropriated water basins are part of the mounting concerns over agricultural in Colorado.

Gas and oil shale development are generally downstream activities from mountain headwaters. In the form of hydraulic fracturing or fracking, this mining activity is dependent upon water. Studies indicate that gas and oil shale development will continue to increase at levels impacting existing water

supply. In 2010, less than one-tenth of one percent of water in the state was used for hydraulic fracturing (Colorado Oil and Gas Conservation Commission 2016). However, the past decade has seen the expansion of oil and gas drilling adjacent to communities throughout Colorado, concentrated in the eastern plains and western plateaus. Concerns over hydraulic fracturing include issues related to water supply, water spills, contamination of local water supplies and streams, and impacts on groundwater aquifers (EPA 2015).

Colorado Water Governance

Water governance dictates the hydrosocial system. Colorado headwater rivers deliver water downstream to 19 other states and Mexico, providing water resources to approximately 55 billion people. Rivers create connectivity across a broad geographic area, as do the governance structures put in place to manage this resource. The western U.S. has a complex set of rules and regulations that rely upon cooperation and coordination at local, state, national, and international governance levels.

The headwaters of Colorado are carefully managed based on the doctrine of prior appropriation ("first in time, first in right"), established water rights for beneficial use (senior and junior rights), and interstate and international compacts that articulate water sharing and allocation. The state of Colorado has numerous municipalities, public utilities, ditch companies, and water districts that manage water flows. In 2015, the Colorado Water Plan was completed to provide guidance on strategies to meet future water demands. Within the state, water is transported across watershed divides via natural waterways, ditches, storage reservoirs, and tunnels to meet agricultural and municipal needs. While there are approximately 44 such diversions, in Colorado the majority of these (35) shift water across the continental divide to eastern Colorado. For example, seventeen ditches and tunnels move water from the west slope to the South Platte River Basin to meet the domestic and agriculture needs in Front Range communities (Colorado Office of the State Engineer 2005).

Colorado collects data on surface flows from the major river basins. These measurements are critical for annual water planning and foundational for meeting interstate and international agreements (Figure 4). Several interstate compacts manage water sharing and allocation with downstream states. For example, the Colorado River Basin is central in defining water management in the western U.S. The Colorado River Compact (1922) between the states of the upper Colorado River Basin (Wyoming, Colorado, Utah, and New Mexico) and the lower basin states (California, Arizona, and Nevada) define the allocation of water rights of the river. International water agreements are also important. Overseen by the International Boundary Water Commission (IBWC), the 1944 Boundary Treaty addresses international water allocation with Mexico focusing on the Colorado, Tijuana, and Rio Grande Rivers.

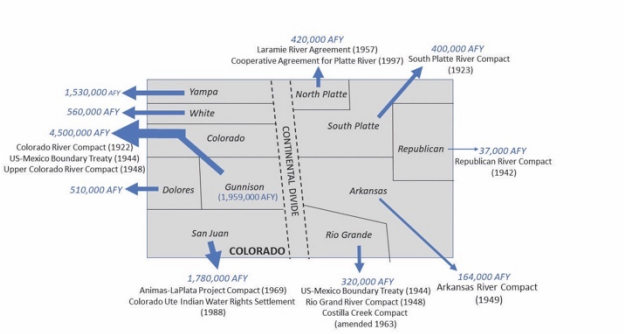

Figure 5. Surface Water Flows from Colorado River Basins and out-of-state Compacts (acre-feet per year) (Colorado Water Knowledge 2020).

The Colorado Water Plan (State of Colorado 2015) situates Colorado as a leader in transdisciplinary water management and stakeholder collaboration. The CWP provides a roadmap of action items to meet explicit water management goals and objectives built upon a series of state-wide Roundtable activities. Another outgrowth of Colorado water management is the growing number of watershed groups representing stakeholders organizing across the state. Initiated in the early 2000s, the Colorado Watershed Assembly facilitates a network of organizations and provides resources to water organizations. A list of active watershed groups indicate that there are approximately 90 organizations in Colorado addressing issues related to water quality, aquatic habitats, and water planning (Colorado Watershed Assembly, *n.d.*).

Colorado Headwaters River Basins

These common issues of the hydrosocial system and governance of Colorado river water are compounded by several unique problems in each of Colorado's headwater regions.

Colorado River Basin

The Yampa, White, San Juan, Dolores, and Gunnison Rivers are tributaries to the Colorado River that extends across the western U.S. Each of these watersheds exhibit a variety of issues that expose the changing nature of the western slope of Colorado and the multiple demands upon water resources. The Colorado River is the major western river of the U.S. Southwest. Seventy-five percent of the water originates in Colorado and much of this water flows out of the state to meet compact obligations (State of Colorado 2015). Increasing competition on the Colorado River Basin between water users has led to multiple efforts for collaborative planning, basin studies, and conservation efforts. Coordination with Mexico has resulted in Minute 319 (2012) to better meet the demands at the Colorado River Delta. Innovative water planning to address the anticipated gap in water supply includes creative water banking or water sharing pilot projects. These projects aim to fallow irrigated lands, reduce consumptive water use, and implement conservation efforts in drought years (Colorado River District 2020).

Yampa/White River Basins

Located in the northwestern corner of the state, the Yampa and White river flow west to join the Green River. Yampa is unique in that it remains undammed. The river provides critical habitat for fisheries, rafting and recreation opportunities. Pressures include a changing economy where gas and oil shale development will directly impact water use.

Dolores and San Juan River Basins

The Dolores and San Juan Rivers are located in the southwest corner of Colorado. The San Juan and its tributaries flow through two Native American reservations—the Ute Mountain Reservation and the Southern Ute Indian Reservation. Instream water flow protection is needed for high elevations streams. The region is undergoing a demographic shift with increasing urban development, particularly in the Four Corners region. Legacy impacts from abandoned mines threaten high elevation water resources and downstream communities as evidenced by the Animas River spill in 2015 from the Gold King Mine. This spill contaminated with heavy metals flowed downstream impacting the city of Durango and communities in Utah and New Mexico (Paul and Finley 2015).

Gunnison River Basin

In western Colorado, the Gunnison River Basin is experiencing growth and expansion of small mountain towns (e.g., Crested Butte, Gunnison, Pitkin) in the upper watershed. Adequate water supply strategies are needed as these areas continue to grow. Trans-basin diversions to Colorado's eastern Front Range are of concern to local residents and water users.

Rio Grande River Basin

The Rio Grande drains the southern portion of the state and borders New Mexico. The Rio Grande is considered an endangered river with multiple problems associated with water overuse, rapid urbanization, and international water management. Downstream impacts include municipal water demand, expected to increase by one 100% in the next 50 years, and industrial water use will increase by 40% (International Boundary and Water Commission 2020). The upper Rio Grande experiences risks to water supplies due to changes in snowpack, groundwater recharge, and competing water demands.

Republican River Basin

The Republican River originates in the eastern plains of Colorado. This is a river of critical importance due to the relationship between surface and groundwater. In 2004, the Republican River District was created to coordinate between surface and groundwater issues and work with multiple stakeholders. The river flows over the Ogallala Aquifer where compact compliance is important to river basin health and water planning strategies. The management structure of the Republican River is complex, including both the Republican River Compact (with Kansas and Nebraska) and the Northern High Plains Groundwater Management District.

Arkansas River Basin

The Arkansas is dependent on agriculture and efforts to improve conservation for efficient farming. The Arkansas has approximately ten in-state diversions providing water for agriculture needs (Colorado Department of Natural Resources 2005), a growing tourism industry, and gold medal fisheries. The relationship between water demand and water rights is particularly evident in this watershed. Water rights (generally junior water rights) established during years of high precipitation mean that the basin is over-

appropriated where decreed rights exceed water availability. The aging infrastructure of the water conveyance system needs repair and investment.

South Platte River Basin

Eighty-five percent of Colorado's population live in the South Platte River Basin. Located within the South Platte River basin is the Metro district (Denver and surrounding communities) identified as an explicit water management unit of the Colorado Water Plan. The Front Range communities of the South Platte River Basin drive the future water needs and set the precedent for water planning. Both the Arkansas and the South Platte River basins are critical in determining water sharing strategies that include irrigated agriculture, groundwater management, and municipal supplies. Innovations in water management have been adopted in these basins through alternative transfer methods (ATMs) that allow for temporary, flexible water transfer that is less costly and complicated (WestWater Research for Environmental Defense Fund 2016). Additionally, the South Platte has experienced rapid gas and oil shale development, creating another demand on water supply.

North Platte River Basin

The North Platte Basin is located on the northern border and drains to Wyoming. Water management is linked to irrigation practices and endangered species. Downstream flows are critical for endangered species recovery plans on the Platte River in Nebraska. Efforts to diversify economic opportunities are desired by local communities. The potential to identify new areas for agricultural development will need studies determining and developing unappropriated water in the basin. Additionally, aging water infrastructure repairs are needed to increase water efficiencies.

Conclusion

Colorado's hydrosocial system is a result of long-term coordination between multiple users within the state and across the U.S. West. The rivers have been redesigned to accommodate the human need to move water to where human populations are located. Efforts to ensure upper elevation ecological health have long been a part of Colorado's stewardship of headwater regions. Climate change and economic transitions are driving governments and communities to collaborate in new ways to develop innovative solutions to the looming water crisis.

Mountain runoff provides water for downstream users and ecosystems. Global environmental change, population growth, urbanization, and pollution are all indicators of the age of the Anthropocene where human impacts influence global cycles of carbon, water, and energy (Crutzen and Stoermer 2000; Diaz et al. 2019). Headwaters are particularly vulnerable to fluctuations in global cycles. Equally, local activities impact headwater areas: roads, mining, agriculture, and high-elevation recreation (e.g., ski resorts). Water is the connective element central to future livelihoods, human well-being, and ecosystem health. Innovative, and integrated management built on sound science is necessary to provide water security for future generations.

References

Appenzeller, T. 2019. Fire on the mountain. *Science* 365(6458):1094-1097. doi:10.1126/science.365.6458.1094.

Bixby, R.. S. Cooper, R. Gresswell, L. Brown, C. Dahm, K. Dwire. 2015. Fire effect on aquatic ecosystems: an assessment of the current state of science. *Freshwater Science* 34 (4):1340-1350. doi:10.1086/684073.

Callisto, M. R. Solar, F. Silveira, V. Saito, R. Hughes, G. Fernandes, J. Goncalves-Junior, R. Leitao, R. Massara, D. Macedo, F. Neves, C. Alves. 2019. A Humboldtian approach to mountain conservation and freshwater ecosystem services. *Frontiers in Environmental Sciences* 7 (195):1-12. doi:10.3389/fenvs.2019.00195.

Colorado Department of Natural Resources. 2005. Transmountain diversions. Accessed January 30, 2020. http://water.state.co.us/SurfaceWater/SWRights/WaterDiagrams/Pages/TransbasinDiversions.aspx.

Colorado Office of the State Engineer. 2005. Map of transmountain diversions. https://sciencepolicy.colorado.edu/admin/publication_files/resource-647-wwa_map_3.pdf.

Colorado Oil and Gas Conservation Commission. 2016. Sources and demand for the hydraulic fracturing of oil and gas wells in Colorado from 2010 through 2015. Jointly prepared by the Colorado Division of Water Resources, the Colorado Water Conservation Board, and the Colorado Water.

Colorado River District. 2020. Water banking option. Accessed January 28, 2020. https://www.coloradoriverdistrict.org/water-banking/.

Colorado State Forest Service. 2017. Report on the health of Colorado's forests. Denver, Colorado. https://csfs.colostate.edu/media/sites/22/2018/01/2017_ForestHealthReport_FINAL.pdf.

Colorado Water Knowledge. 2020. Water Uses. Accessed January 6, 2020. https://waterknowledge.colostate.edu/watermanagement-administration/water-uses.

Colorado Watershed Assembly. *n.d.* Watershed groups and soil conservation districts directory. Accessed January 5, 2020. https://www.coloradowater. org/colorado-watershed-basins-map.

Crutzen, P. & E. Stoermer. 2000. The "Anthropocene". *Global Change Newsletter* 41:17.

Dettinger, M., B. Udall, and A. Georgakakos. 2015. Western water and climate change. *Ecological Applications* 27 (3):2069-2093. doi:10.1890/15-0938.1.

Diaz, S., J. Settele, E. Brondizio, H. Ngo, M. Gueze, J. Agard, et al. 2019. Summary for policy makers of the global assessment report on biodiversity and ecosystem services. Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. Bonn, Germany. https://ipbes.net/global-assessment-report-biodiversity-ecosystem-services.

Ellis, E. and N. Ramankutty. 2008. Putting people on the map: anthropogenic biomes of the world. Front *Ecol Environ* 6 (8):439-447, doi:10.1890/070062.

[EPA] Environmental Protection Agency. 2015. Assessment of the potential impacts of hydraulic fracturing for oil and gas on drinking water resources. External Review Draft EPA/600/R-15/047a. https://www.epa.gov/sites/production/files/201507/documents/hf_es_erd_jun2015.pdf.

———. 2019. Superfund National Priorities List (NPL) Where You Live Map. Accessed January 5, 2020. https://www.epa.gov/superfund/search-superfund-sites-where-you-live#map.

Graves, J., A. Ross, S. Feeney. 2017. Colorado abandoned mine water quality study. Colorado Department of Natural Resources, Denver, Colorado. https://www.colorado.gov/pacific/sites/default/files/WQ_Abandoned-Mine-Water-Quality-Study_06-01-17.pdf.

International Boundary & Water Commission. 2020. About the Rio Grande. Accessed January 5, 2020. https://www.ibwc.gov/CRP/riogrande.htm.

Kelly, A. and M. Goulden. 2008. Rapid shifts in plant distribution with recent climate change. *PNAS* 105(33):11823-11826. doi:10.1073/pnas.0802891105.

Korner, C. and E. Spehn. 2019. A Humboldtian view of mountains. *Science* 365 (6458):1061. doi:10.1126/science.aaz4161.

Lukas, J. 2018. Climate change in Colorado: recent trends, future projections and impacts - an update to the executive summary of the 2014 report. University of Colorado, Boulder. https://www.colorado.edu/climate/co2014report/ExecSummary_Climate_Change_CO_Report_update_August2018.pdf.

Martinuzzi, S., S. Stewart, D. Helmers, M. Mockrin, R. Hammer, V Radeloff. 2010. The 2010 wildland-urban interface of the coterminous United States. USDA.

Messerli B., D. Viviroli, and R. Weingartner, 2004. Mountains of the world: vulnerable water towers for the 21st century. *Ambio* 13:29-34. doi:10.5167/uzh-110516.

Millennium Ecosystem Assessment. 2005. *Ecosystems and human well-being: Synthesis*. Island Press, Washington, DC.

Minute 319. 2012. Fact sheet: Interim international cooperative measures in the Colorado River Basin through 2017 and extension of Minute 318 cooperative measures to address the continued effects of the April 2010 earthquake in the Mexicali Valley, Baja California. https://www.ibwc.gov/Files/Minutes/Min319_Env_Fact_Sheet.pdf.

Mitchell, K. 2018. Colorado's 2018 wildfire season one of the worst on record, and it's not over yet. *Denver Post*, August 18. https://www.denverpost.com/2018/08/18/colorado-worst-wildfire-season2018/ clearUserState=true.

Parmar, S., T. Doherty, P. Nichols, J. Jay, K. McCarty. 2018. Sharing water to save the farm: a guide to agricultural-municipal water sharing for Colorado's land conservation community. Colorado Open Lands, Denver, Colorado.

Paul, J. and B. Finley. 2015. Animas fouled by 1 million gallons of contaminated water. *Denver Post*, August 6. https://www.denverpost.com/2015/08/06/animas-river-fouled-by-1-million-gallons-of-contaminated-mine-water/.

Radeloff, V. C., R. B. Hammer, S. I. Stewart, J.S . Fried, S. S. Holcomb, J. F. McKeefry. 2005. The wildland-urban interface in the United States.

Ecological Applications 15: 799-805. doi:10.1890/04-1413.

Schoennagel, T., J. Balch, H. Brenkert-Smith, E. Dennison, B. Harvey, M. Krawchuk, N. Mietkiewicz, P. Morgan, M. Moritz, R. Rasker, M. Turner, and C. Whitlock. 2017. Adapt to more wildfire in western North America forests as climate changes. *PNAS* 114 (18) 4582-4590. doi:10.1073/pnas.1617464114.

State of Colorado 2015. Colorado Water Plan: Overview of Each Basin. Accessed January 6, 2020. https://dnrweblink.state.co.us/cwcb/0/doc/199501/Electronic.aspx?searchid=80d50cb3-95bf-405c-bfa5-587c633c7136.

Svaldi, A. 2018. Three Colorado mountain towns rank in top five in U.S. for growth in senior population. *Denver Post,* February 14. https://www.denverpost.com/2018/02/14/colorado-mountain-towns-senior-citizen-population/.

[UN] United Nations. 2013. What is Water Security: Infographic. UN-Water. https://www.unwater.org/publications/water-security-infographic/.

Venable, N., R. Lockwood, J. DiMaria, J. Duda, C. Rhoades, L. Mason. 2017. Forest management to protect Colorado's water resources – a synthesis report to support House Bill 16-1255. Colorado Water Conservation Board, Denver, CO.

Vincent, C., L. Hanson, C. Argueta. 2017. Federal land ownership: Overview and data. Congressional Research Service 7-5700, Washington D.C. https://www.crs.gov.

Water Education Colorado. 2015. Citizen's guide to Colorado water law. Denver, CO. https://issuu.com/cfwe/docs/wl4_r9_web.

WestWater Research for Environmental Defense Fund. 2016. Alternative water transfers in Colorado: a review of alternative transfer mechanisms for Front Range Municipalities. Denver, CO. https://www.edf.org/sites/default/files/alternative-water-transfers-colorado.pdf.

Wohl, E. 2001. *Virtual Rivers: Lessons from mountain rivers of the Colorado Front Range*. New Haven, CT: Yale University Press.

World Population Review 2019. Colorado Population 2020. Accessed January 6, 2020. http://worldpopulationreview.com/states/colorado-population/.

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FROM TAILWATERS TO URBAN WATERS: ANGLING AND CONSERVATION ON COLORADO'S SOUTH PLATTE RIVER

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Colorado is home to a variety of fisheries: dammed rivers, freestone (unregulated) streams, mountain creeks, beaver ponds, lakes, and reservoirs. In these fisheries, and across the Rocky Mountain West, the form of angling known as fly fishing has greatly increased in popularity alongside broader trends in growth of the outdoor recreation industry and amenity migration to the region (Gosnell and Abrams 2011). In this chapter we detail the socio-ecological landscape of Colorado's South Platte River, focusing on angling and conservation in two unique riverine environments: the tailwater fisheries downstream of bottom-release dams and the urban stretch of river running through Denver and its suburbs (Figures 1 and 2). The South Platte tailwaters are known for their abundant trout and dramatic mountain scenery, while in the Denver metropolitan area the South Platte is plagued by problems associated with industrialization and urban and suburban development. The tale of these waters is in part a story of contrasts: rural versus urban, trout versus carp, mountain paradise versus urban sewer. It is also, however, a story of connections: between upstream and downstream, humans and environment, anglers and fish. The tailwater and urban stretches of the South Platte could hardly seem more different, but together they embody key questions about how 'nature' is manufactured, how recreation and conservation are entangled, and how perceptions of species and place are co-constituted.

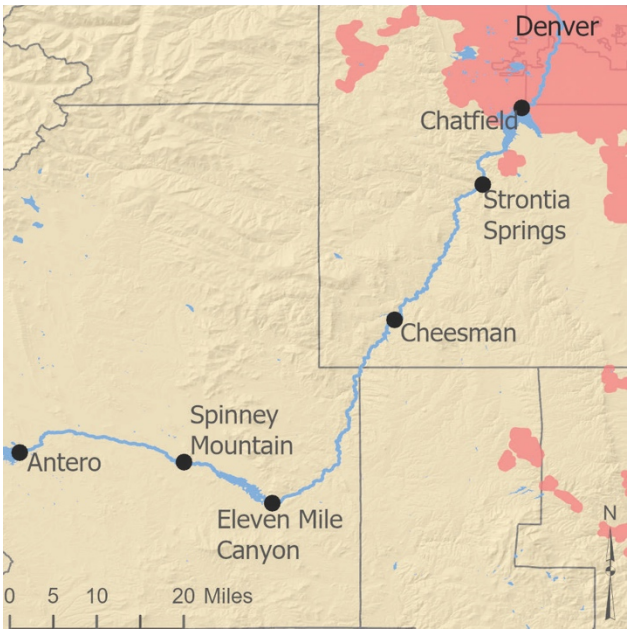

Figure 1. Map of dams on Colorado's South Platte River.

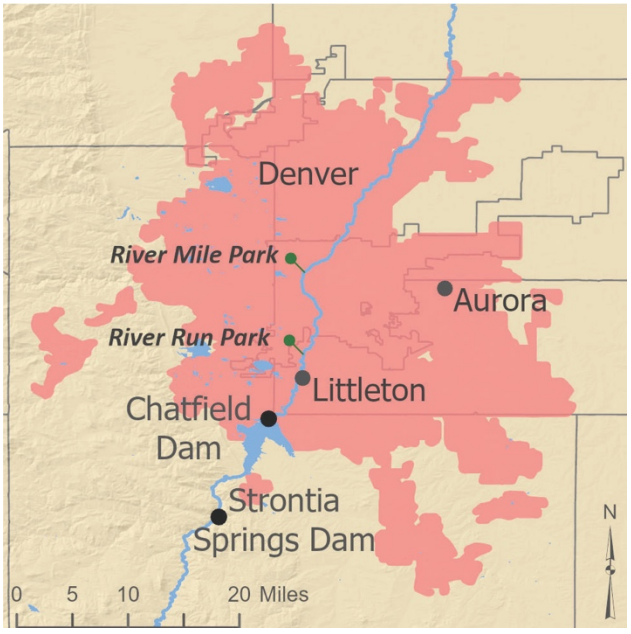

Figure 2. Map of urban stretch of South Platte River through Denver and suburbs.

Tailwater Fisheries

Writing of the South Platte, Colorado fly fishing author John Gierach (1988) waxed, "This river is everything a trout stream should be" (140). A former director of Colorado Trout Unlimited claimed that the South Platte is "our holy water—the shrine of trout fishing in this state" (quoted in Knudson 1987, 12). Cheesman Canyon, the South Platte's most productive tailwater fishery, is "fly fisher's paradise in its purest form" (Dorsey 2019, ix), and the stretch of river between Spinney Mountain Reservoir and Eleven Mile Reservoir is so idealized that it goes by

the moniker "Dream Stream." This discourse reinforces a romantic and nostalgic view of the South Platte as a natural, wild and unrestrained river brimming with trout. This imagery is in turn used to market and sell fishing and outdoor gear, guide trips, real estate, beer, and numerous other commodities (Baginski and Biermann 2010). But even as angling the tailwaters of the South Platte is put forth as an antidote to modernity, civilization, and urbanization, these famed trout fisheries are undeniably modern, byproducts of massive concrete impoundments and carefully managed hatchery systems of trout reproduction.

The tailwater fisheries of the South Platte River are the products of a series of dams and reservoirs constructed in the twentieth century as water storage systems for the burgeoning city of Denver and its suburbs (Table 1). Tailwater fisheries are found downstream of bottom-release dams, where the cool water released from the bottom of a reservoir helps to maintain consistent water temperatures. This causes tailwaters to remain ice-free in winter and cool in summertime, providing anglers with "a kind of man-made spring creek" (Gierach 1992, 57). Because of their consistent temperatures, tailwaters experience year-round insect emergences. On the South Platte, regular midge hatches occur throughout winter, providing winter dry-fly (surface) angling opportunities (Dorsey 2019). Tailwaters are also less affected by storms and sediment discharge than freestone streams, making flow volume and water clarity relatively constant (Dorsey 2009). With consistent flows, the banks of tailwater streams are stable and not prone to severe erosion. Vegetation establishes on stable banks, which supplies organic matter to the river and provides habitat for invertebrates (Engle 1991).

The biological communities of tailwaters are distinct from freestone streams, with large populations of crustaceans such as scuds, sow bugs, and worms that serve as high-protein food sources for trout. These conditions cause trout in tailwaters to be both larger in size and in number than in undammed streams (Engle 1991). Several tailwater stretches of the South Platte have such immense biomass that they are designated Gold Medal Water, meaning that they are publicly accessible waters that support a minimum of 60 pounds of trout biomass per acre and 12 quality size (14" or larger) trout per acre (Colorado Parks and Wildlife 2019). With over fourteen times this amount, the tailwater below Cheesman Dam on the South Platte far exceeds the requirements for gold medal status. In 2016, an electrofishing survey of Cheesman Canyon by Colorado Parks and Wildlife (CPW) recorded a whopping 4,555 rainbow trout and brown trout per mile and 859 pounds of trout biomass per acre (Spohn 2016).

These novel ecosystems of insects, crustaceans, and non-native trout (rainbow trout, brown trout, Snake River cutthroat trout (above Eleven Mile Reservoir), and brook trout (above Spinney Mountain Reservoir)) have spurred innovation in fly patterns and angling techniques over the past half-century. On the South Platte, anglers began to find that traditional fly patterns tied on relatively large-sized hooks were inadequate for fooling tailwater trout, which subsist on a diet of miniscule midges, scuds, sowbugs, mayflies, and aquatic worms (Brown 2015). Prior to the 1960s, hooks smaller than size 20 were virtually nonexistent, and poor-quality feathers, clunky vises, and thick threads made tying small flies especially challenging (Gierach 1990; Krumm 2016). As smaller hooks, synthetic materials, and genetic hackle (feathers from chickens that have been selectively bred for fly tying materials) became available, Colorado fly designers experimented with imitating the small bugs common on the South Platte tailwaters: midges, baetis mayflies, and nymphal or larval stages of aquatic invertebrates. Colorado fly designers inspired by the South Platte are responsible for some of the most common tailwater fly patterns used today: Copper John, Brassie, RS 2, Jujubaetis, and Buckskin among them (Dorsey 2015).

The impact of the South Platte tailwaters on fly fishing more broadly—and the sport's impact on Colorado in turn—is reflected in the preponderance of angling innovators in the state. Two of the largest fly-tying genetic hackle companies are in Colorado: Whiting Farms (Delta, Colorado) and Umpqua Feather Merchants (Louisville, Colorado). Umpqua Feather Merchants is also known for their innovative fly designs, and among their professional team of over 150 Signature Fly Designers, nearly a third are based in Colorado (Dorsey 2015). In addition, the method of fishing weighted nymphs is believed to have originated on the tailwaters of the South Platte (referred to by historian Jen Brown (2015) as the South Platte technique). This technique is now commonly used not only in Colorado but throughout the world.

This diffusion of flies and techniques was made possible by the manufactured and uniform nature of tailwaters. While the South Platte may be unique in

Table 1. Dams on the South Platte River upstream of Denver, Colorado, listed from upstream to downstream.

Dam	Owner/Operator	Year Constructed
Antero	Denver Water Board	1909
Spinney Mountain	City of Aurora	1981
Eleven Mile	Denver Water Board	1932
Cheesman	Denver Water Board	1905
Strontia Springs	Denver Water Board	1983
Chatfield	US Army Corps of Engineers	1975

some respects, its tailwaters are similar in ecosystem structure and composition to tailwaters throughout western North America (and thanks to the translocation of species, to tailwaters elsewhere in the world as well) (Snyder, Borgelt, and Tobey 2016). While impounding a river has produced stellar angling opportunities on the South Platte, the negative impacts of dams are not negated. On coastal rivers, dams prevent anadromous fish from migrating upstream to spawn. On inland rivers, altered conditions (temperature, flow, etc.) contribute to declines of native species, as has been the case of native cutthroat trout on the South Platte. Furthermore, the South Platte's dams present tensions between water allocation priorities and fisheries management. The unpredicttability of flows at the hands of dam operators (in this case, Denver Water and the City of Aurora) vexes both anglers and conservationists. As Gierach writes, "Some of us think of the [Denver] Water Board as a malevolent natural force—the modern equivalent of evil spirits" (1992, 52).

Eleven Mile Canyon, the tailwater below Eleven Mile Reservoir, illustrates the challenges of providing water for municipal and industrial use while maintaining optimal ecological conditions (Figure 3). After recording trout population declines in the 1990s, in 2000 Colorado Division of Wildlife (now CPW) instituted new catch and release and artificial lures/flies only regulations on the uppermost two miles of the fishery (Dorsey 2019). Despite the regulations, trout fry numbers continued to decrease, from 1088 in 2004 to 421 in 2005 to a mere 23 in 2008 (Johannson 2012). Gradually fisheries managers began to understand the decline as the product of streamflow management decisions that resulted in irregular flows. In the years since, CPW has collaborated with Denver Water, which operates Eleven Mile Dam, and the City of Aurora, which operates the next dam upstream, Spinney Mountain, to collaboratively manage flows in Eleven Mile Canyon during rainbow trout spawning season (May-June). Because Denver Water uses Eleven Mile Reservoir as a drought reserve, it does not release water unless the reservoir is at or above capacity or if the area is experiencing severe drought. The streamflow into Eleven Mile Canyon is therefore determined primarily by the amount of water released from Spinney Mountain Reservoir by the City of Aurora. Under the current agreement, when necessary, Denver Water loans water to the City of Aurora from its downstream Strontia Springs Reservoir, and the City of Aurora pays Denver Water back later in the season with water from Spinney Mountain Reservoir (Willoughby 2012). This arrangement appears to be relatively successful thus far in maintaining the trout population. Still, anglers express frustration with the unpredicttable flows that result from water managers treating the river like a tap that can be turned on or off at will.

Figure 3. Eleven Mile Canyon, below Eleven Mile Reservoir, on the South Platte River. To maintain cool water temperatures, Denver Water blends warmer spill water from the top of the reservoir with cooler water released from the bottom of the reservoir.

In 2019, following above-average snowpack, Denver Water and the City of Aurora allowed Spinney Mountain and Eleven Mile Reservoirs to fill up before matching incoming and outgoing flows. Once the reservoirs reached capacity, huge amounts of water were released, far exceeding average discharge and making angling on the Dream Stream and Eleven Mile Canyon near impossible for over a month of the prime summer season.

Even as they enjoy tailwater fisheries, angler-conservationists are vocal in their opposition to dams. Writer Gary LaFontaine explains: "Let me admit a bit of hypocrisy: whenever a dam is proposed I try through individual effort and membership in conservation organizations to stop its construction; but if I had to make a list of my favorite trout fisheries it would include many tail-water rivers—some of them resulting from the very dams I worked hard to prevent" (quoted in Brown 2015, 122). The South Platte provides a case in point. In the 1970s, as Denver's population swelled and with it residential and industrial demands for water increased, Denver Water began to actively pursue the Two Forks Dam project, located just downstream of the confluence of the main stem of the South Platte and its North Fork. The proposed reservoir would store 1.4 billion m^3 of water and flood 50 km of the South Platte valley, including some of the most productive and accessible trout waters (Luecke 1999). The dam was particularly attractive to Denver Water as it would provide additional storage capacity for water transferred via tunnels across the Continental Divide from the Colorado River and its tributaries. As the project underwent the National Environmental Policy Act (NEPA) review process, opposition mounted and gained national media attention. Angler groups such as Trout Unlimited played a crucial role in the opposition, alongside other environmental organizations, by highlighting the invaluable trout fishery, unique species (the threatened Pawnee montane skipper butterfly), and abundant recreational opportunities that would be impacted (Luecke 1999). After a long and protracted political process, in 1990 the Environmental Protection Agency (EPA) vetoed the necessary permit for Two Forks Dam as a violation of the Clean Water Act. Two Forks Dam would not be built, and between Cheesman Dam and Strontia Springs Dam, the produced paradise of the South Platte would continue to flow freely.

The Urban South Platte

As the South Platte continues its descent from the eastern edge of the Rocky Mountain Plateau into Denver, the river's postcard-worthy canyon walls are replaced by interstates, railyards, parking lots, a football stadium, amusement park, and power plant (Figure 4). Consistent with broader trends of neglect and mistreatment of urban waterways, the urban South Platte endured decades of treatment as little more than an urban sewer (Simpson 2018).

Figure 4. The South Platte River from the East 47th Avenue bridge in Denver.

By the time the river reaches the city, it no longer retains the conditions characteristic of tailwaters. Daily maximum water temperatures in the urban South Platte reach 24-26° C (76-78° F) in summer, far exceeding optimal temperatures for trout (U.S. Geological Survey 2019). Additionally, flows are highly variable depending on drought conditions and upstream water management decisions. Despite these obstacles, some angling interests are attempting to convert the South Platte into an urban trout fishery. Examples include experimental trout stocking programs in Littleton and Denver, along with habitat modifications to create respite for trout during warm summer water temperatures (Figure 5). Despite efforts to further manufacture the South Platte into a trout stream, the urban South Platte is already home to several warmwater fish species, including the non-native common carp (C*yprinus carpio*).

Introduced to the U.S. in the mid-nineteenth century as a food source, carp populations expanded rapidly and for most of the twentieth century carp in the U.S. were viewed as "trash fish" and deemed unworthy of pursuit by fly fishers (Monahan 2017), "a species more likely to be pursued with a bow and arrow than a bead-head nymph" (Santella 2012). Due to their large size, visibility, and tolerance to

Figure 5. The Johnson Habitat Park along the South Platte in Denver sits on the site of a former landfill. The park is part of a broader effort through the River Vision Implementation Plan (RVIP), a collaborative initiative of the City and County of Denver, Trust for Public Lands, and the Greenway Foundation to clean up and restore the urban South Platte.

pollution, the stereotypical image of the carp is often of a garbage-eating fish in polluted urban waters. While the carp, an omnivorous opportunist, will take advantage of any available food sources, including food scraps offered by humans, its typical natural diet is similar to other more highly regarded fish, such as smallmouth bass and trout.

Perceptions of fly fishing for carp changed greatly in the late 1990s with the publication of *Carp on the Fly: A Fly Fishing Guide*, a book written by three Front Range anglers, based largely on their experiences in the South Platte watershed (Reynolds, Befus, and Berryman 1997). The text challenged the long-held taboo by providing a how-to guide for pursuing the much-maligned species with a fly rod and reel. The book, and the underlying idea of pursuing the carp with a fly rod, spawned a revolution in angling as conceptualizations of what fly fishing could be changed significantly. Images of casting a perfectly tied microscopic midge pattern to rising trout in a postcard-worthy canyon became juxtaposed with wading in water that tested positive for *e. coli,* worrying about hooking a shopping cart, all in the pursuit of a fish that is widely considered a nuisance.

Twelve years after the publication of *Carp on the Fly*, an article appeared on the front page of the *Wall Street Journal* discussing the brave new world of fly fishing for carp on the South Platte in downtown Denver (Scheck 2009). In a drastic turn of events, carp are now referred to by many in the angling community as "freshwater bonefish," a comparison to the highly sought-after fish that resides in shallow tropical saltwater (Licis 2010; Monahan 2017). Denver fly shops now provide fishing reports for carp in the South Platte along with the more traditional angling destinations such as the tailwater trout fisheries upstream from the city. Indeed, fly fishing for carp has become so popular that the Denver chapter of Trout Unlimited is now in its second decade of hosting its annual Carp Slam tournament on the South Platte.

Denver is among the ten fastest-growing large cities in the U.S., and with that growth has come increased traffic and congestion (U.S. Census Bureau 2019). For many, the prospect of devoting potentially hours of waiting in traffic to escape the city and venture to one of the South Platte's tailwater trout paradises has become less appealing. The urban stretches of river in and around Denver provide an accessible alternative, which Silver (2016) equates to "heading out to your local par 3 golf course." Perceptions and treatment of the urban South Platte are changing as the city and its residents work to reimagine the river. Examples of this include the South Platte Urban Waters Partnership, a collaborative EPA pilot project to reconnect Denver with its river, The River Mile, a proposed neighborhood along the South Platte, marketed as "A place where the city and nature come together" (Revesco Properties n.d.), and the creation of a series of standing waves for river surfing in River Run Park. The urban river, despite receiving more attention and care than a few decades ago, still suffers from *e.coli* and heavy metal pollution (Sanchez 2019). Thus, avid urban South Platte angler Will Rice notes, "You can't do anything worse to that river, so the more people we can get out there enjoying it as a recreational resource and caring about it as a river, the better" (quoted in Lucchesi 2012).

Transformations in Angling and Conservation

As the South Platte flows downstream, it morphs from an iconic tailwater trout paradise to an urban fishery whose future is yet undecided. This transformation is illustrative of broader changes in both angling and conservation. Fly fishing as a sport is moving from a purist, elitist, and trout-focused endeavor to one that embraces the anthropogenic realities of novel, humanized ecosystems, as seen in the increasing popularity of carping on the South Platte. The great irony, of course, is that 'pristine' tailwaters such as Eleven Mile and Cheesman Canyons are no less manufactured than the urban sections of the South Platte. Alongside this shift, there are signs that fly fishing may be becoming more diverse and

inclusive: female participation is increasing rapidly, and more affordable equipment has entered the market, though the sport remains overwhelmingly white and male (Clarke 2017). In the story of the South Platte we also see how angling interests have shaped conservation, restoration, and water management practices. Upstream, angling interests have opposed additional dam projects and helped to institute more fish-friendly water management practices and catch-and-release policies. Downstream, angling interests are altering fish habitat, encouraging recreational use of the urban river, and contributing to a broader re-imagining of the South Platte.

References

Baginski, J., and C. Biermann. 2010. Montana on the fly: a state hooked on trout. *FOCUS on Geography* 53 (4):142-147. doi: 10.1111/j.1949-8535.2010.00017.x.

Brown, J. C. 2015. *Trout culture: How fly fishing forever changed the Rocky Mountain West*. Seattle: University of Washington Press.

Clarke, J. 2017. Fly fishing targets women as a source for growth. *New York Times*, December 10.

Colorado Parks and Wildlife. 2019. Colorado Parks and Wildlife Commission Policy: Wild and Gold Medal Trout Management. https://cpw.state.co.us/Documents/Commission/2019/June/Item.15a-POLICY_Wild_Gold_Medal-Katie_Lanter-DNR.pdf.

Dorsey, P. 2009. *Fly fishing tailwaters*. Mechanicsburg, PA: Stackpole Books.

Dorsey, P. 2015. *Colorado guide flies*. Mechanicsburg, PA: Stackpole Books.

Dorsey, P. 2019. *Fly fishing guide to the South Platte River*. Guilford, CT: Stackpole Books.

Engle, E. 1991. *Fly fishing the tailwaters*. Harrisburg, PA: Stackpole Books.

Gierach, J. 1988. *The view from Rat Lake*. New York: Simon and Schuster.

Gierach, J. 1990. *Sex, death, and fly fishing*. New York: Simon and Schuster.

Gierach, J. 1992. *Even brook trout get the blues*. New York: Fireside.

Gosnell, H., and J. Abrams. 2011. Amenity migration: diverse conceptualizations of drivers, socio-economic dimensions, and emerging challenges. *GeoJournal* 76 (4):303–322.

Johannson, B. 2012. New angle on trout troubles. *Aurora Sentinel*, May 11.

Knudson, T. J. 1987. Colorado's 'shrine of trout fishing' is in danger. *New York Times*, October 23.

Krumm, B. 2016. Fly tyers name greatest innovations in craft. *Billings Gazette*, May 19.

Licis, C. 2010. Carp: the fresh-water bonefish. *Denver Post*, July 20.

Lucchesi, N. City fishin' in the South Platte River can only get better, says angler Will Rice. *Westword*, May 10.

Luecke, D. F. 1999. Two Forks: the rise and fall of a dam. *Natural Resources & Environment* 14 (1): 24–69.

Marvar, A. 2019. Fly fishing is the new bird-watching. *New York Times*, October 14.

Monahan, P. 2017. Fish facts: everything you wanted to know about the common carp but were afraid to ask. *Orvis News*, May 3.

Revesco Properties. n.d. The river mile. Accessed January 10, 2019. https://www.rivermiledenver.com/.

Reynolds, B., B. Befus, and J. Berryman. 1997. *Carp on the fly: A fly fishing guide.* Boulder, CO: Trails Books.

Sanchez, H. 2019. Denver's South Platte has plenty of fish: Think hard before you put one in your month. *Colorado Public Radio*, June 3. https://www.cpr.org/2019/06/03/denvers-south-platte-has-plenty-of-fish-think-hard-before-you-put-one-in-your-mouth/.

Santella, C. 2012. Carp gain as a fly-fishing favorite. *New York Times*, February 12.

Scheck, J. 2009. On fly casting's urban frontier, the fish are big, the water's dirty. *Wall Street Journal*, March 19.

Silver, G. 2016. A backyard river for the Front Range angler: The South Platte. *RootsRated*, March 11. https://rootsrated.com/stories/a-backyard-river-for-the-front-range-angler-the-south-platte.

Simpson, K. 2018. After long regarding the South Platte as not much more than a sewer, is metro Denver ready to love its river? *Colorado Sun*, October 1.

Spohn, J. 2016. Cheesman Canyon fish survey and management information. Accessed January 2, 2019. https://cpw.state.co.us/thingstodo/Fishery%20Survey%20Summaries/SouthPlatteRiverAtCheesmanCanyon.pdf.

Snyder, S., B. Borgelt, and E. Tobey (eds.) 2016. *Backcasts: A global history of fly fishing and*

conservation. University of Chicago Press: Chicago.

U.S. Census Bureau. 2019. Fastest growing cities primarily in the South and West. Accessed January 10, 2019. https://www.census.gov/newsroom/press-releases/2019/subcounty-population-estimates.html.

U.S. Geological Survey. 2019. National Water Information System data: South Platte River at Englewood, Colorado. Accessed January 4, 2019. https://waterdata.usgs.gov/nwis.

Willoughby, S. 2012. A cooperative effort has replenished wild trout on the South Platte. *Denver Post*, April 24.

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FOOTPRINTS IN THE SAND: CULTURAL ECOLOGY OF THE FRONT RANGE FROM THE PREHISTORIC TO THE POSTINDUSTRIAL

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It is easy in this techno-genic age to imagine ourselves as being insulated from, or immune to, the vagaries of nature. However, with climate change creating ever more obvious impacts in our lives, it is useful to examine how deeply affected humans are, and have always been, by the environment. Denver is a particularly interesting place to conduct such an exercise, because it is one of the oldest continuously inhabited parts of North America, and thus we can observe people adapting to this landscape over thousands of years, amidst severe climatic fluctuations. It is also a place that is popularly viewed through the lens of wilderness, so it is easy to overlook this history. From the Folsom hunters' adaptation to the decline of big game to the ski industry's use of silver iodide to improve snowfall, Colorado's landscapes have constantly challenged and forced new innovations, patterns of mobility, and forms of social organization. This essay is a limited survey into the unique accommodations and relationships people have had with the land from the prehistoric to the postindustrial, and an attempt to introduce the reader to some of the most fascinating places in the state.

Footprints in the Snow: Cultural Ecology of the Front Range

In many folks' geographical imaginations, Colorado calls forth mountains, forests, and canyons. More above-treeline acreage exists here than any other state in the continental U.S. It is easy to imagine one's self standing where few have before. Citing the harshness of the environment, and the notion that mountainous regions are "culturally peripheral," archeologists had stayed out of the high country (Benedict 1992, 1), assuming, as many of us do, that these are the margins of human existence. But layered atop our perceptual landscape of wilderness is a deep human history, one that stretches back in time further here than almost anywhere else in North America. James Benedict's foundational archeological study, *Footprints in the Snow*, is not only academically important and filled a massive lacuna in high-altitude archaeology, but it is a compelling story, at once an archeological detective story, piecing together the mystery of ancient stone features in the Rocky Mountain tundra, and a thrilling tale of migration and adaption to the environment.

Rollins Pass and the Indian Peaks Wilderness

Looking west from Denver, the wall of mountains is framed by two of the tallest peaks in the state—in the north, the flat-topped prominence of Long's Peak, and south, the rounded massif of Mount Evans. Between the two is a chain of shorter but equally impressive peaks called the Indian Peaks (Figure 1). Roughly in the middle of this jagged cordillera is a low saddle, connecting the South Fork of Boulder Creek to the headwaters of the Colorado River. So obvious is this route across the mountains that it became the main thoroughfare for Euro-Americans—first a wagon road, then a railroad, and later a tunnel for trains, and pipeline carrying water across the mountains (Wright and Wright 2018). The palimpsest of Rollins Pass is impressive, and ubiquitous if you know where to look. Yet the visual landscape belies those historical laminations—aside from the fading tracks of 4-wheelers and the old railroad grade, the landscape above treeline lacks any obvious imprint of human activity. It is, after all, in the Indian Peaks Roadless Wilderness Area.

Approaching Rollins Pass from the western side, one bounces up a rutted railroad grade through thick conifer and aspen forests until breeching treeline around 11,000 feet, revealing an expansive viewshed of tundra and mountain peaks tumbling away to the plains on either side. If you've never been in the high country before, it is intoxicating. Your eyes are always drawn distant—50, 75, 100 miles. The visual spectacle of beholding so much of the earth's surface is overwhelming (and the lack of oxygen contributes to a legitimate light-headed feeling!). Archeology at this altitude faces unique challenges. The wind is powerful enough to sweep away all but the heaviest artifacts. What might be left on the ground can be

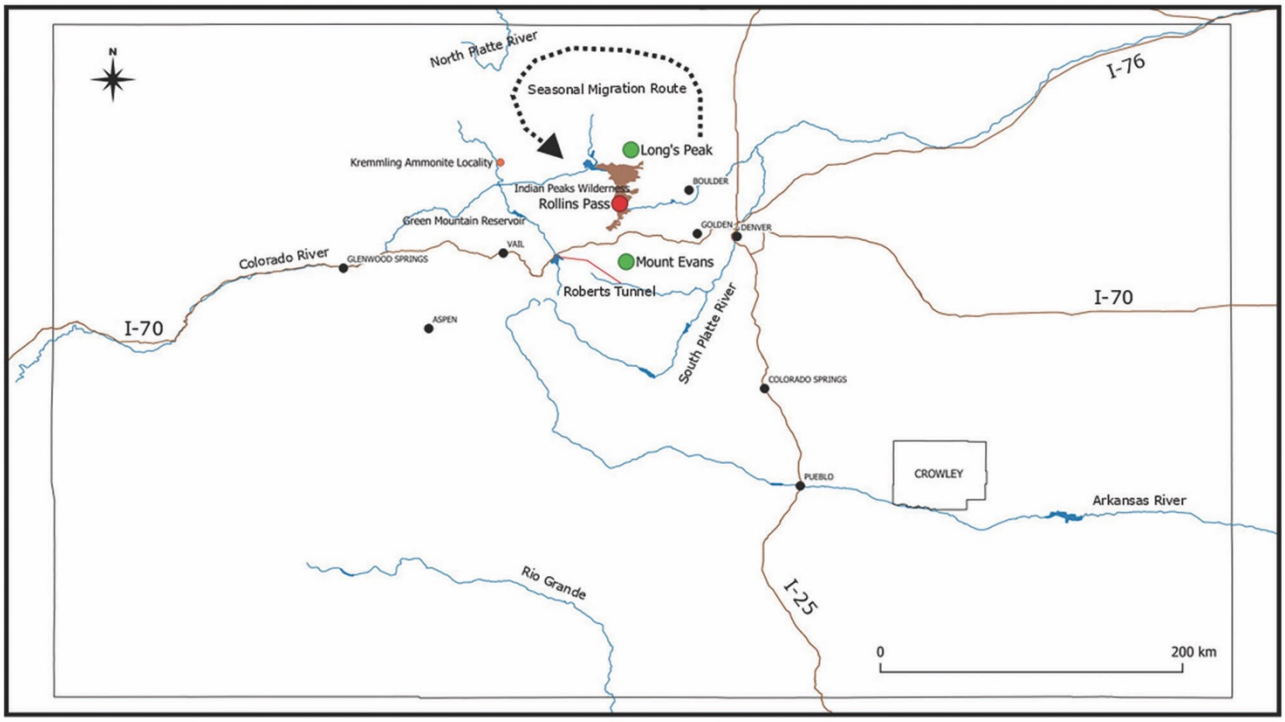

Figure 1. Map of locations discussed in this essay.

rapidly swallowed up by the constantly moving permafrost, which also displaces surface layers, making chronology difficult, and rendering purposefully built cairns and rock fences indistinguishable from naturally occurring *felsenmeer* (blockfields created through frost-heaving action which are common in the alpine tundra). That there were artifacts and stone structures in the Indian Peaks was common knowledge in Colorado during the settlement period—the toponymy reflects the evidence Euro-Americans found in abundance there. Remarkably these features escaped much serious academic scrutiny into the late 20th century. In true Colorado fashion, archeologists became mountain climbers and sought to understand who made these features, and what purpose they served.

The most prominent archeological features on Rollins Pass are game-drive fences, some hundreds of yards long, punctuated periodically by circular hunting blinds made of stacked boulders (Figure 2). Camps were made on lower slopes, below treeline, where animals—primarily bighorn sheep—were butchered and processed. Excavations at multiple sites in Colorado have revealed use extending back over 8000 years. Two "seasonal transhumance

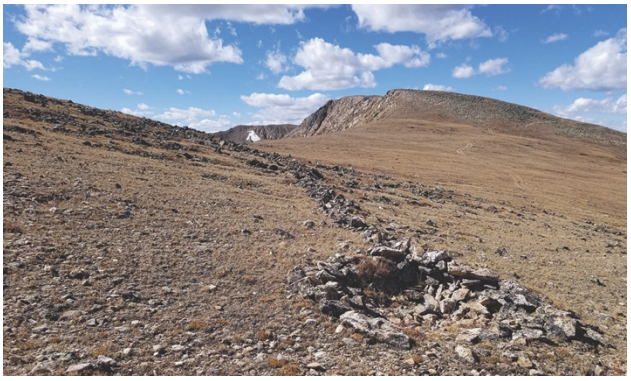

Figure 2. A hunting blind and game fence at the Olson Site. Photo by the author.

systems" are evident in the archeological record: one, the older system (5800-5300 YBP), consisting of an up and down movement from the Front Range hogback zone in winter to the high-altitude hunting grounds in the summer; the second system, which Benedict describes as "rotary" is evidenced around 1500 YBP through the late-prehistoric era, and perhaps surviving up until the contact period (Benedict 1992). The people who utilized this system wintered in the moderate climate of the Front Range foothills, taking advantage of lower altitude and

adiabatically-warmed Chinook winds, as well as the numerous caves, rock shelters and canyons. Hogback zone archeological sites such as Magic Mountain in Golden (Figure 3) and LoDaisKa in Morrison have been occupied nearly continuously since the Paleo-Indian period, but it is during the Early Ceramic Period (150-1150 AD) that the settlements are at their largest and most extensive (LaBelle and Pelton 2013; Gilmore 2003). In spring, as the lower valleys and canyons greened, people living in the hogback zone set out north, seeking snow-free passage into Middle Park and North Park, resource bases not only for food, but for quality stone tools, required to hunt game at high altitude, which they did towards the end of summer, hunting above treeline until the first snows came when they would descend back down to their winter abodes (Benedict 1992).

Figure 3. Pictographs associated with the Magic Mountain Site in Golden, CO. Photo by the author.

Ancient Human-Environment Relationships

The diverse climates created by temperature-altitude zonation produce differential patterns of abundance and scarcity. Similarly, the varied geological terrain of the Rockies is rich in natural resources, but upon a broken landscape of rivers, canyons, mountains and plateaus. Benedict (1992) concludes that these seasonal transhumance patterns were dictated, and sustained over millennia, in large part by environmental factors; seven to be exact:

> *(1) a location at the headwaters of four major river systems in the semiarid interior of the continent, (2) abundant late-lying and perennial snowbanks that made the region virtually immune to drought, (3) a severe periglacial climate that restricted human habitation to warm seasons and to intervals without excessive snow, (4) convenient access to mild wintering environments and low-altitude resources, (5) a lack of good-quality tool stone at high elevations, (6) a scarcity of edible plants that could be harvested in large quantities, and (7) extensive tundra uplands that attracted bighorn, elk, and other large ungulates in summer.*

The unique attributes of the Front Range influenced human geographies to a remarkable degree, according to Benedict "(n)o factor has influenced human occupation of the Front Range alpine region more dramatically than climate" (1992, 2). Shifts in climate led to the transition from Clovis to Folsom traditions on the Great Plains around 12,000 YBP, but in the Rockies, the "up-down" game drive system was innovated during a severe regional drought that peaked around 5700 YBP—Mount Albion complex, a tradition associated with the Arctic, specialists in tundra hunting, suddenly appear in the archeological record at high-altitude in the Southern Rockies. The drought, which induced colder and drier conditions across North America, drove the Mount Albion people south, where they found a niche in the alpine tundra of Colorado.

These mountains were anything but culturally peripheral, as Benedict and his colleagues discovered. Although the high country, the plains, and canyons had been inhabited by numerous discrete cultural groups over thousands of years of history from the paleolithic to the present, each developed similar adaptations to the diverse landscapes of Colorado and the Rocky Mountain West. Today, new groups of humans continue to settle in this region, but in spite of global influences and changing demographics, the physical landscapes of Colorado continue to impose themselves upon the people who settle here.

Booms and Busts

Spend any amount of time in Colorado and you will notice a particular manifestation of life in a tourist hotspot—the locals are defensive, and proud! The "Native" bumper sticker—although designed by a non-native to mock this instinct in locals during the 1970s oil boom years (Kenney, 2018)—is a reaction to the influx of tourists to the state, as well as the migration of out-of-staters that happens in boom cycles. Things haven't changed much from the Gold

Rush days—booms and busts are part of the settlement pattern of the West in general (as are periods of populism, xenophobia, and intolerance to outsiders). The boom that had the most enduring impact on Colorado, however, was not one spurred by precious metals, but by perceptions of the healthfulness of the environment.

In terms of numbers, it was asthmatics and "lungers," (a 19th century colloquialism for people infected with tuberculosis) that outnumbered the miners and trappers and cowboys in the settlement of the West (West 1998). Perceptions of the Middle West as disease-ridden and filled with "miasma" drove tens of thousands of wagons straight on through the Mississippi Basin and on to healthier pastures in the West (Nash 2006). The most influential and fastest growing cities were places like Glenwood Springs, Colorado Springs, and Boulder, which boasted high-class sanitoriums for sick urbanites fleeing dank industrial cities (Sherlock 2013). Doc Holliday may be the most famous of these, and Buffalo Bill summered in Golden in his later years to escape the stifling humidity of his Nebraska ranch (and wearying schedule of the Wild West Show), but tens of thousands of migrants came to Colorado in search of not just a "better life" but very explicitly for a more healthful one. Fast forward to the 21st century—Colorado ranks as the fittest state in the nation (McCann 2019), and the perceived healthfulness of the climate (and the recreational opportunities to keep you healthy) are huge draws for migrants of all demographic groups, but particularly millennials attracted to the outdoor lifestyle, miles of trails, national parks, and ski resorts.

The environment influences our human migrations at different scales as well—weekend traffic to the mountains is perhaps the most obvious example of this. Just as ancient people congregated along regularly trafficked routes to the high country to take advantage of unique resources available there, so do we in the modern age. Except instead of driving big game in the tundra, we drive to the tundra to "shred powder" (a 21st century colloquialism for skiing or snowboarding). Weekend warriors from the Front Range migrate to the high country, displaying remarkably predictable patterns of mobility and leaving their marks on the landscape as well. Instead of piles of knapped flint, trash middens, and rock walls, these migrants leave impacts on much larger scales. One major impact of all this human mobility, is, of course, climate change. So, considering that shifts in paleoclimate had profound impacts not just on where ancient people lived, but how they lived—what might the future hold for migration patterns in Denver and the Rocky Mountain West?

Dams and Diversions

Currently, the Rockies in Colorado tend to get equal amounts of precipitation from winter/spring snow (midlatitude cyclones) as from summer convective precipitation (southwest monsoon). Increasingly, summer flash floods are a concern, with the 2013 floods being a prime example of the kinds of events we expect more often in the future as a result of anthropogenic climate change. In addition, warmer winters (and more dust and soot) spell doom for the snowpack which melts faster each year. This changes the calculus of the state's largest water users and water delivery infrastructure—which is primarily designed to capture spring runoff from snowmelt.

After reaching the so-called end of the era of big dams in the 1970s, there has been a spurt of new dam construction in Colorado, driven by storage concerns amidst rising drought frequency and intensity, and increasing demand. Denver Water is nearing groundbreaking for the expansion of Gross Reservoir on the South Fork of Boulder Creek; a tributary not coincidentally fed by Arapaho Glacier, Colorado's largest remaining ice body, which is expected to be gone by 2070 (Haugen et al. 2010), removing a large contribution to summer flow in South Boulder Creek and increasing the need to store spring snowmelt. The City of Golden used eminent domain in the first decade of the 21st century to condemn property on the West Fork of Clear Creek that would become Guanella Reservoir—allowing that small municipality to store water delivered from the Western Slope (Figure 4). Wolford Reservoir near Kremmling, was completed in 1995 to ensure that Western Slope users would have a reliable source of water, as more and more is promised down-stream and piped up over the mountains to the east. Wolford's upper reaches lap at Cretaceous sedimentary formations which are home to the Kremmling Locality—a world renowned site for ammonite fossils, also called the "Bird Bath Site" (Figure 5)—calling back to another ancient episode of climate change, when Colorado was equatorial ocean.

The impacts of climate change in terms of when and where water goes are open questions for Colorado, as they are for many places around the world. People will move where the water goes, and

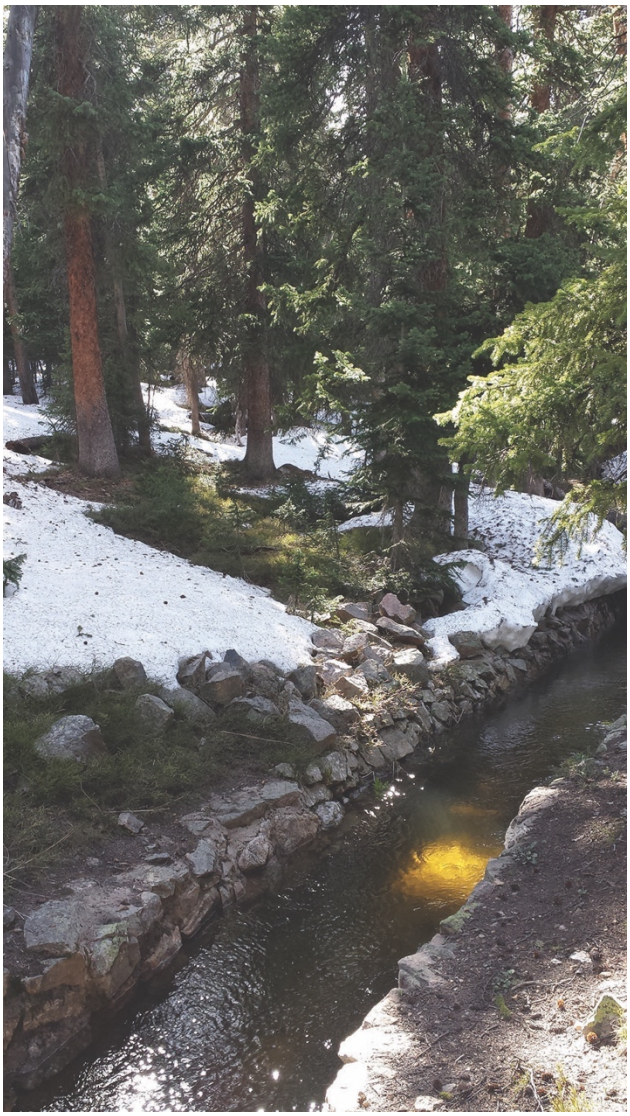

Figure 4. Modern stoneworks in the high-country: At 11,341 feet above sea level, Berthoud Pass ditch captures snowmelt from Current Creek (which flows into the Colorado via the Fraser River) and diverts it through a tunnel to the West Fork of Clear Creek. From there, the water is stored in the newly constructed Guanella Reservoir—which the City of Golden used eminent domain to acquire and construct in 2003. Photo by the author.

this has been happening in Colorado for eons. As Benedict noted, the location at the headwaters of four major rivers systems was a parameter that enabled the unique high-altitude transhumance systems, and it also helps explain the early Euro-American settlement of the state. The major cities and population centers of Colorado rose to prominence because of their ability to access distant water resources. The Front Range is where most of the people are, but, as a result of the rainshadow effect produced by the orographic barrier of the Rockies, the water is all on the Western Slope. For over a century, water diversions, some of immense and impressive scale, bent nature towards humans. The Roberts Tunnel, for example, is 23 miles long, and bores 4000 vertical feet through the Continental Divide, dumping a good chunk of the Blue River—a river tributary to the Colorado—into the North Fork of the South Platte.

Figure 5. Giant fossil ammonite at the "Bird Bath Site" near Kremmling, CO. Wolford Mountain, the namesake of Wolford Reservoir—one of Colorado's newest water storage facilities—is hidden from view in this image, but would be just off to the right (east); photo is looking southeast. Photo by the author.

Increasingly, major diversions appear to be pipe dreams, as Western Slope interests have grown in political and economic, if not demographic, power. The economic impact of tourism and recreation—supported in large part by flowing rivers for rafters and anglers—changes the equation. Historically, the value added to diverted water outweighed any adverse impact on Western Slope economies. However, now the prospect of adding a thousand homes in suburban Denver at the expense of a billion-dollar whitewater and fishing industry is not quite as alluring. As

it becomes increasingly difficult for the metropoli of the Front Range to divert the water they need to sustain growth, migration flows may shift to the Western Slope—and locations such as the Roaring Fork Valley attest to this nascent movement of people and investment to the windward side of the Rockies. The Roaring Fork Transit Authority now offers daily public bus service from Glenwood Springs to Aspen. The Glenwood Springs Micropolitan Statistical Area now contains roughly 80,000 residents and is growing at a nearly 6% annual rate. Similarly, the Vail-Eagle-Edwards corridor is a cosmopolitan urban area high in the mountains, complete with an international airport and even a Sam's Club.

Concerns about water and the impacts its availability or absence has on human geographies in the state are not limited to the high country. The Eastern Plains of Colorado are underlain by the Ogalala Aquifer, and the agricultural economies there depend upon groundwater. Since the 1880s, cattle drives moved up through Colorado's eastern plains to railheads like Denver and Julesburg. Cattle were sent to stockyards in Kansas City, Omaha, and Chicago for finishing with Midwestern-grown grain, then butchered and transported to East Coast markets. But in the 1980s, the industry shifted dramatically—newly developed center-pivot irrigation, refrigerated trucks, interstate highways, and hybrid corn technologies all converged to break the grip that nature held over beef production. Corn only grows with rain east of the 100th meridian, and cattle pasture best in low humidity shortgrass prairies west of it. Most people lived in the east far away from both. There was a vast resource beneath the sands of the Great American Desert that promised to break the bonds of this geography.

That natural resource—the Ogalala—revolutionized the livestock industry, allowing corn to be grown in the arid steppe, right next to the best rangeland in the world, and the advent of interstate highways and refrigerated trucking meant that meat could be butchered in remote places on the Plains and sent to market without spoiling. Eastern Plains towns that grew during one climatic episode—the settlement of the West largely coinciding with a pluvial period lasting from about 1890-1930—and collapsed under the weight of another—the Dust Bowl—experienced another boom in the 1980s and 1990s as former dryland farmers and cattle ranchers built wells and became irrigation farmers supplying feed to the stockyards of Lamar, LaJunta, Greeley, and the Golden Triangle in southwest Kansas. But in the 2000s the prognostications of hydrologists—the most hated of fortune tellers in the West—started to come true: a prolonged drought from the late 1990s through the 2010s was aiding the rapid drawdown of the Ogalala (Frankel 2018). Creeks and springs began to dry up. The water table dropped precipitously, starving rivers of groundwater contributions to baseflow. I drove over the Arkansas River for the first time in my life in 2009, excited to see one of the great rivers of the American West—from Dodge City to Pueblo, I didn't see a drop of water, and the only evidence of a river was the ribbon of tamarisk and willows that broke the bleakness of the drought-stricken plains. Where will the last residents of these plains ghost towns go? If history is any lesson, they will move to Denver. Or pack up and head to Bakersfield like so many Okies before.

Already the desertification is occurring, though not because of climate necessarily. Crowley County, in southeast Colorado's plains, along the Arkansas River, benefitted from mountain diversions for decades (Figure 6). A prosperous irrigation community, thriving on melons, sugar beets and wheat, thanks to a tunnel built bringing water from the Roaring Fork River—a Western Slope tributary of the Colorado—to the Arkansas Basin via Twin Lakes Reservoir. But the water rights to distant mountain snowmelt held by the farmers of Crowley County were coveted by the growing cities of Colorado Springs, Pueblo, and Aurora, and throughout the 1980s and 1990s development companies bought land and water rights from local farmers, eventually acquiring a majority of the county's 50,000 irrigated acres. In the 2000s, the companies cashed in their water rights and sold out; known as "buy and dry," the deals moved water away from Crowley County towards urban areas. The people followed. Crowley's last stockyard went bankrupt in 2015. While not a direct outcome of climate change or draining of the Ogalala Aquifer, the fate of Crowley County provides an analog for what we might expect on the rest of the Great Plains as the Ogalala is drained.

Footprints in the Sand: Towards an Archeology of the Postindustrial

The recent growth of the Denver metro area is not an isolated phenomenon limited to the Front Range, it is part of a much larger regional rural-to-urban migration trend in the Great Plains and Rocky

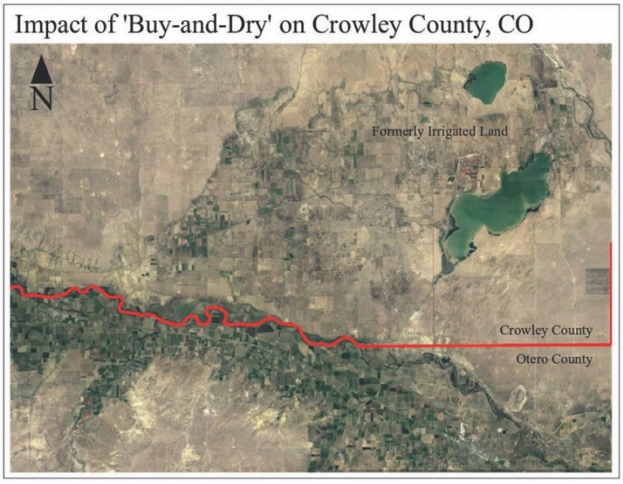

Figure 6. In this 2019 satellite imagery over southeastern Colorado, the boundary between Crowley County and Otero County is shown in red. The Arkansas River valley cuts across the bottom half of the image. The Otero County portion is green, with planted fields of Rocky Ford melons, alfalfa, soybeans and corn for the livestock industry. Crowley County's formerly irrigated lands, about 50,000 acres worth, now lies fallow and brown, a haven for Russian Thistle (*kali tragus*) and other invasive species (Google Earth, annotations by the author).

Mountain West. Since the peak of Great Plains Euro-American settlement in the 1920s, most rural counties have consistently lost population in each subsequent census (Popper and Popper 1987). However, regional urban centers have taken those rural migrants. Flows of migration from small towns and rural places in the West to larger regional urban centers increase during times of economic or environmental stress, and decrease during periods of plenty—just as they did for ancient people (Gilmore 2008). A future of a drained Ogalala Aquifer is one in which these pre-existing migration flows will amplify once again, and it is likely that Denver will continue to be the destination for a large portion of these rural migrants.

So today, though we continue to be mesmerized by the romantic notion of wilderness, Coloradans and Westerners are uniquely tied to their environments in similar ways as ancient people. The distant mountains, so dramatic and alluring, are far from remote, and are woven deeply into the fabric of our everyday lives. Our migrations are influenced by the availability of resources relative to one place over another. Our bodies and minds are shaped by our interactions with a unique natural landscape—we have a dozen words for snow in Colorado, and people have tattoos of the famous Colorado license plate! And, in spite of our technological prowess and impressive infrastructure, it is hubris to banish the thought that Eisenhower and Johnson Tunnels may one day resemble as many ancient rock fences crumbling in the permafrost.

References

Benedict, J. B. 1992. Footprints in the snow: High-altitude cultural ecology of the Colorado Front Range, U.S.A. *Arctic and Alpine Research* 24 (1): 1-16.

Frankel, J. 2018. Crisis on the High Plains: The loss of America's largest Aquifer—the Ogallala. *Denver Water Law Review*, May 17. Accessed January 16, 2020. http://duwaterlawreview.com/crisis-on-the-high-plains-the-loss-of-americas-largest-aquifer-the-ogallala/.

Gilmore, K. P. 2008. Late Prehistoric State (A.D. 150-1540). In *Archaeological Landscapes on the High Plains*, eds. Schieber, Laura L. and Bonnie J. Clark. Boulder: University Press of Colorado.

Haugen, B. D., T. A. Scambos, W. T. Pfeffer, and R. S. Anderson. 2010. Twentieth-century changes in the thickness and extent of Arapahoe Glacier, Front Range, Colorado. *Arctic, Antarctic, and Alpine Research,* 42 (2):198-209.

Kenny, A. Surprise Colorado: The guy invented those "Native" bumper stickers is a transplant. *Denverite*, May 25, 2018. Accessed January 16, 2020. https://denverite.com/2018/05/25/surprise-colorado-natives-inventor-beloved-bumper-sticker-utah/.

LaBelle, J. M. and S. R. Pelton. 2013. Communal hunting along the continental divide in Northern Colorado: Results from the Olson game drive (5BJ147), USA. *Quaternary International* 297: 45-63.

McCann, A. 2019. Fattest states in America. *WalletHub.com*, November 5. Accessed January 16, 2020. https://wallethub.com/edu/fattest-states/16585/.

Nash, L. 2006. *Inescapable ecologies: A history of environment, disease, and knowledge*. Los Angeles: University of California Press.

Popper, D. J. and F. E. Popper. 1987. The Great Plains: From dust to dust, a daring proposal for dealing with an inevitable disaster. *Planning*, 53 (1):12-18.

Sherlock, T. J. 2013. *Colorado's healthcare heritage: A chronology of the nineteenth and twentieth centuries,* Vol. 1:*1800-1899*. Bloomington, IN: iUniverse.

West, E. 1998. *The contested plains: Indians, goldseekers, and the rush to Colorado.* Lawrence: University Press of Kansas.

Wright, T. B. and K. Wright. 2018. *Rollins Pass*. Mount Pleasant, SC: Arcadia.

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PARTNERING WITH INDIGENOUS COMMUNITIES TO ADDRESS THE ENVIROMENTAL HEALTH LEGACY OF ABANDONED MINES IN THE WESTERN UNITED STATES

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Abandoned Mines in the Western United States

Mineral resource extraction in the United States has had significant repercussions on the environment, cultural histories, and human health. The nineteenth century mining boom in the western United States, catalyzed by the discovery of gold ore in California, transformed the land and resources there into a political economy of extraction and expansion (Voyles 2015). The emergent cultural landscapes[1] of mining communities throughout the west shaped race relations around labor and the displacement of Indigenous people (Sheridan 1998; Hardesty 1998). Hundreds of thousands of prospectors flooded California and the surrounding territories during the gold rush (Starr and Orsi 2000). As the productivity of alluvial placer deposits waned, the mining industry was transformed from one dominated by prospecting to large-scale industrialized operations (Sheridan 1998). As a consequence, the mining boom has pocked the west with abandoned hard rock mines.

According to the U.S. Environmental Protection Agency [EPA], abandoned mine lands (AMLs) are the lands, waters, and watersheds surrounding places where mining or ore processing[2] has occurred or is temporarily inactive (EPA 2015). The U.S. Geological Survey (USGS) has identified more than 100,000 of these sites in the 48 conterminous states (Ferderer 1996). More recently, the U.S. Government Accounting Office [GAO] conducted a detailed assessment of available information about abandoned hardrock mines in the western United States. The GAO concluded that comprehensive, detailed information about abandoned mines does not exist because of a patchwork of state-level programs that identify, locate, and address abandoned mine issues. The GAO estimated that more than 160,000 abandoned mines exist in the western U.S. (GAO 2008) with more than 500,000 mine features (Nazarro 2008). The legacy of these abandoned mines has

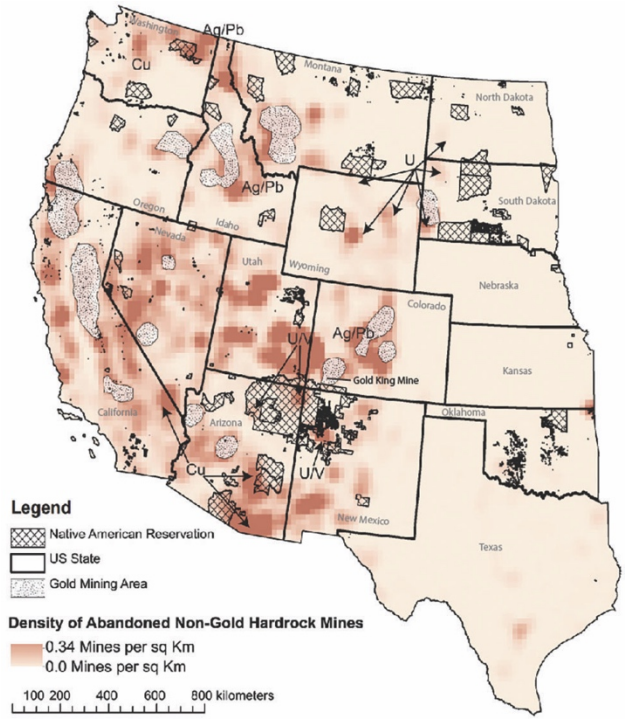

Figure 1. Spatial distribution of abandoned hardrock mines in the western United States. Adapted from Lewis, Hoover and MacKenzie 2017—distributed under the Creative Commons Attribution 4.0 International License (http://creativecommons.org/licenses/by/4.0/)

[1] The notion of emergent cultural landscapes here is based on Carl Sauer's *Morphology of Landscape*, but our research seeks to balance his insistence that "what man does in an area...involves use of environment rather than active agency of the environment" (Sauer 1925), with Indigenous ontologies of environmental agency and management (Muller, Hemming, and Rigney 2019).

[2] The EPA definition of AMLs does not include coal production, which is under the purview of the Department of the Interior.

resulted in numerous environmental and human impacts, including a pronounced detriment to Indigenous communities.

Legacy of Abandoned Mines in the Western United States

Previous research by our group cataloged the spatial distribution of abandoned hardrock mines in the western United States, using available data from the USGS (Figure 1). Results indicated that more than 600,000 Native Americans lived within 10km of an abandoned hardrock mine (Lewis, Hoover, and MacKenzie 2017). We also determined that gold mines were the most common type of abandoned mine in the region, followed by uranium and vanadium mines. There are more than 4,000 abandoned uranium mines (AUMs) in the western United States (EPA 2008), including AUMs on or proximal to tribal reservations. For example, the decommissioned Homestake Uranium Mill (Figure 2) situated between Laguna Pueblo and the Navajo Nation was operational between 1958 and 1990 (EPA 2011). Physical remediation of hazards at the site, such as covering the 21 million tons of mill tailings with topsoil and fencing off the perimeter, started in 1993 (EPA 2020). This site is listed on the EPA National Priorities List for CERCLA cleanup (EPA 2016). The presence of AUMs plus the sociodemographic, infrastructural, public health, and environmental challenges on or near Reservation areas increases the possibility of exposure disparities for communities in these areas (Lewis, Hoover and MacKenzie 2017). Furthermore, the practice of traditional lifeways, including consumption of grazing livestock meats, may increase contact with environmental media (Harper et al. 2012) thereby increasing exposure if resources are negatively impacted by historic mining activities.

Abandoned mines represent an ongoing environmental and public health challenge. Occasionally, a mine related event makes national news. For example, in August 2015, a retaining wall at the Gold King Mine located in southwest Colorado was accidently breached. As a result, 11,300 m^3 of water drained from the mine into tributaries of the Upper Colorado River basin – this includes Cement Creek, a tributary of the Animas and San Juan Rivers. The spill turned the river a bright yellow color (Figure 3) – compelling downstream communities to close water intake pipes, cease irrigation, and wonder about the fate of the mine waste in the water.

Figure 2. Water misting the larger of two tailings piles standing more than 100 feet high and covering 200 acres at the Homestake Uranium Mill site near Grants and Milan, NM. Photo by Daniel Beene, University of New Mexico.

Figure 3. Yellow water is visible downstream of the Gold King Mine more than one week after the spill initiated on August 5, 2015 (EPA https://www.epa.gov/goldkingmine).

Subsequent environmental monitoring indicated that approximately 172,365 kg of solids were released during the spill including iron, aluminum, lead, manganese and other metals (Chief et al. 2016). In October 2015 the EPA established the Gladstone Interim Water Treatment Plant to remove metals in mine discharge and the plant remains operational (EPA 2020). Previous work by our research colleagues indicates that metals in the Animas River adhere to the mineral jarosite and are released when geochemical conditions change (Rodriguez-Freire et al. 2016). Remobilization of metals in surface water suggests a potential for exposure for communities along the Animas and San Juan Rivers.

Mining and Historical Trauma

In the 1930s, biologists with the U.S. government described lands of the Navajo Nation as devoid of vegetation and natural beauty at the fault of improper livestock grazing by the Navajo people (Voyles 2015, p. 27). Subsequently, the U.S. Government ordered the slaughter of cattle, goats, and sheep, reinforcing the colonial notion that this land was "empty except for Indians" (Voyles 2015, p. 236). Uranium ore prospecting on the Navajo Nation and other tribal lands was borne out of this sentiment and girded by nationalism at the height of the Cold War (Amundson 2002). Uranium prospecting reinvigorated the colonial attitude of westward expansion and was popularized through the likes of print media referring to the Colorado Plateau as "America's energy storehouse" and a "fabulous treasure house of energy" (Voyles 2015), and songs like Elton Britt's "Uranium Fever" in 1955. The mostly Anglo prospectors flooded the West equipped with Geiger counters, and if ore deposits were discovered an open pit or underground mine often would soon follow. The U.S. government, as the only legal purchaser of uranium ore, subsidized uranium prospecting and created a decade-long boom followed by an equally long bust beginning in the 1950s. As governmental control over uranium loosened in the 1970s a second decade-long mining boom was propped up by the private energy sector (Amundson 2002; Gedicks 1993). The last uranium mine on the Navajo Nation closed in 1986 (Marlow 2017), and despite cleanup efforts and the enactment of the Diné Natural Resource Protection Act of 2005 (DNRPA), which bans the production and mining of uranium on Navajo land, tremendous environmental health impacts persist.

Exposure to Metals in the Southwest United States

There are thousands of abandoned hardrock and uranium mines in the Southwest U.S. Metals found in the wastes at these sites are transported by water and air. Previous exposure assessment research in the region indicated potential exposure to environmental metals via dust inhalation (Beamer et al. 2014). Environmental and anthropogenic disturbances may increase transport of dust contaminated with heavy metals from mining sites to larger regions (Bogle, Redsteer, and Vogel 2015). Ingestion of water that contains metals found in abandoned mine waste is also a prominent concern for communities in the region (Hoover et al. 2019; de Lemos et al. 2009) since AUM pollutants may also be transported via surface water in ephemeral or perennial drainages. Previous research found that environmental media in drainages downstream of AUMs contain metals found in AUM waste because of high water solubility of contaminants (de Lemos et al. 2009; Lameman Austin 2012).

Geospatial technologies have been frequently adopted in environmental exposure studies that involve a large geographic area and communities in rural areas (Winde et al. 2019; O'Rourke et al. 1999). For example, EPA's Navajo Nation AUM Screening Assessment Report (EPA 2007) found increased metal concentrations in soil and water as proximity to AUMs decreased. Our research group previously compiled water quality information for studies conducted by tribal, state, federal, non-profit, and academic groups over a 30-year period to evaluate spatial patterns of metal occurrence in groundwater. We observed a spatial trend with decreasing concentrations of arsenic and uranium as distance from the nearest AUM increased (Hoover et al. 2017). The co-occurrence of uranium and arsenic was also evaluated and 3.9% of the tested unregulated water sources on the Navajo Nation simultaneously exceeded both the arsenic and uranium maximum contaminant level (MCL), 10 and 30 $\mu g\ L^{-1}$, respectively. A follow-up investigation identified distinct mixtures of metals in groundwater sources, including the frequent co-occurrence of uranium, arsenic, and manganese in UWSs (Hoover et al. 2018). Spatial analysis of the metal mixtures indicated spatial clustering of unregulated water sources with concentrations of uranium, arsenic, manganese and other metals exceeding Safe Drinking Water Act MCLs in historic uranium mining districts of the Navajo Nation (Hoover et al. 2018).

Many existing contaminant fate and transport models require sophisticated and comprehensive environmental data, which is commonly lacking in the rural western U.S. A geographic information system (GIS)-based multi-criteria decision analysis (MCDA) approach can relate known and observable effects of multiple exposure routes from pollution sources to the neighboring landscape (Malczewski 2006; Jiang and Eastman 2000). A recent study has demonstrated its effectiveness and accuracy in evaluating combined environmental exposures in the Navajo Nation (Lin et al. 2020).

Human Health and Mine Waste Exposures

Experimental and epidemiologic data collected in partnership with indigenous populations are sparse; however, available evidence does indicate an association between metal exposure and adverse health outcomes among populations in the Southwest (Gonzales et al. 2018). The Diné Network for Environmental Health (DiNEH) project was initiated to address the broader public health effect of environmental exposures to un-remediated uranium mine and mill sites. Researchers from the University of New Mexico worked with 20 Chapters from the Eastern Agency of the Navajo Nation (Figure 4). The community-based project integrated community members into the research design and implementation to facilitate culturally appropriate survey questions. Research team members, which included trained community members, administered surveys and reviewed answers so that responses were correctly interpreted. The project recruited 1,304 participants from eastern Navajo Nation.

Figure 4. Mine tailings and waste in Church Rock, NM (Eastern Agency Navajo Nation), site of the Northeast Church Rock and Quivira Mines. Photo by Daniel Beene.

Study results indicated that human exposures to mine waste during the active mining era were associated with increased risk of kidney disease. Comparatively, the study also found that those individuals with ongoing exposures to mine waste, after active mining ceased, had an increased likelihood for hypertension (Hund et al. 2015). Subsequent investigations relied on geospatial analysis of residential home and AUM locations to explore the relationship between AUM waste exposure and cardiovascular disease. Laboratory analyses indicated a strong positive association between residential location and biomarkers of inflammation (Harmon et al. 2017), and elevated oxidized low-density lipoprotein production, which is a biomarker that may indicate cardiovascular disease risk in the study population (Harmon et al. 2016). Researchers also observed evidence of autoimmune disruption among Eastern Agency residents that was associated with uranium ingestion via drinking water (Erdei et al. 2019). Other studies with indigenous communities in the Southwest and Mountain West areas of the U.S. indicated that arsenic exposure is positively associated with diabetes, cardiovascular disease, chronic kidney disease, and increased lung and prostate cancer mortality. Cadmium exposure was also associated with cardiovascular and coronary heart disease mortality and overall cancer incidence (Gonzales et al. 2018).

Ethical Considerations of Geospatial Technology

The legacy of uranium mining in and around the Navajo Nation is replete with environmental and historical trauma as discussed above. As with other sciences, GIS can run the risk of assimilating Indigenous ways of knowing into Eurocentric ones (Reid and Sieber 2019; Rundstrom 1995). This is because the approximation of real-world processes must rely on assumptions that are standardized using conventional spatial ontologies, which are built on agreed-upon definitions of objects and their relationships both in reality and in data models (Agarwal 2005; Agrawal 2002). Reid and Seiber (2019) argue that ontologies ought to be built on Indigenous language and interpretations of the physical world. Moreover, the assumptions on which geospatial models rely propagate error and uncertainty in model results (Zhang and Goodchild 2002). A subset of computational modeling science is devoted to understanding and quantifying uncertainty as a function of measurement error, simplification of reality, and statistical inference (Abbaspour, Vaghefi, and Srinivasan 2017). However, it is not appropriate or necessarily useful to Indigenous communities facing environmental health disparities to simply report uncertainty in the form of what models cannot predict or accurately represent. Rather, inclusion of Tribal members in the interpretation of results enhances the modeler's ability to communicate risk and promote health and safety from community-based Indigenous lived experiences (Giles, Castleden, and Baker 2010).

Case Study: Mining Impacts on the Navajo Nation

There are more than 500 abandoned uranium mines (AUMs) and thousands of AUM features, such as tailings, pits, adits, and vents within the boundaries of the Navajo Nation. There are also four uranium mills on Navajo land (Lewis, Hoover, and MacKenzie 2017), including the Church Rock uranium mill, where a catchment pond for contaminated runoff water disastrously breached and flowed into the Puerco River in 1979. Uranium contamination in drinking water sources downstream from the spill site have exceeded MCLs for more than a decade (Lewis, Hoover, and MacKenzie 2017). The Navajo Nation borders on and includes portions of the Grants Mineral Belt, where uranium mining was prolific, including numerous claims on Mount Taylor to the east, which holds significant cultural and religious connotations to at least eight Native tribes (Benson 2012). In January 2020, Rio Grande Resources, the owner of the Mount Taylor mine, announced that the operation there will permanently close after 20 years of standby status (Chamberlain 2020). Indeed, the geography of uranium mining on the Navajo Nation is not merely an artifact of a colonial past but a present and dynamic reality that shapes the lives and livelihoods of Navajo people and their relationship with their land.

Communities throughout the Navajo Nation confront the legacy of AUMs daily. To address community concerns about AUMs we have partnered with a Navajo community, Diné College, Northern Arizona University, University of New Mexico, and Montana State University Billings to conduct a collaborative, community-driven research project. The community is located in the Northern Agency of the Navajo Nation in northeastern Arizona and is located in a watershed that includes dozens of AUMs (Figure 5). Community members are concerned about negative human health impacts and potential contamination of traditional cultural resources such as plants, animals, and livestock, from the nearby mines and waste.

The research partnership is using a transdisciplinary approach to investigate AUM exposure of domesticated livestock and uptake of metals in animal tissues. The goal of this study is to examine the geospatial and temporal grazing patterns of domesticated livestock to inform GIS models of potential for human exposure to metals found in AUM waste through consumption of traditional foods from livestock. The study objectives include:

Figure 5. Livestock wearing GPS collars to track their grazing patterns in a watershed in northeast Arizona that contains abandoned uranium mines. Photo by Daniel Beene.

1. Spatial modeling of livestock grazing patterns;
2. Assessment of livestock contact with abandoned mines and waste;
3. Measurement of livestock organ uptake of metals found in AUM waste; and
4. Assessment of the potential human exposure to metals via consumption of traditional foods.

The contributions of GIScience to this research are diverse. Using geospatial technologies and methods to investigate the spatiotemporal patterns of livestock behavior, we can begin to estimate the potential environmental exposure for livestock. Exposure is based on environmental risk modeling, which incorporates the quantification and interpretation of uncertainty. Recurring discussions with livestock owners and other community members have allowed us—in partnership with the community—to validate and calibrate the models based on local knowledge. Active interpretation of the spatial data has also informed sampling strategies of water sources and biotic material in the watershed for laboratory analysis of contaminants. Ultimately, the results will be related to metals analysis of livestock tissues to interpret the overall finding of livestock exposure. The partnership with community leaders and researchers from the Tribal college will enable study results to be interpreted within the framework of Navajo cultural practices and beliefs and relayed to residents in a sensitive and culturally appropriate manner. Results from this study will also be used by regulators and other decision makers to evaluate the

primary community concern motivating the larger study-potential for human health risk from consuming meat and organs from livestock grazing in the watershed. The collaborative partnership formed to conduct this study facilitates a culturally and community appropriate approach that collects information that is useful to both the community and regulators working to reduce mine waste exposures in the watershed.

Summary

The presence of abandoned mines throughout the western United States presents community members and decision makers with both acute and chronic challenges. The environmental impacts of historic mining remain and affect contemporary human health through multiple exposure pathways. Indigenous communities may be disproportionately impacted by abandoned mine waste coupled with infrastructure and sociodemographic challenges that inhibit the capacity to respond to and reduce exposures. Interdisciplinary research partnerships facilitate cross-cultural communication, engagement, and cooperation. There remain opportunities for geographers to work with colleagues to address known and emerging environmental and human health issues associated with abandoned mine waste. There are also ample opportunities to work with communities in rural and underserved areas to address these challenges to reduce human exposures, return environmental conditions to balance, and improve human health.

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References

Abbaspour, K., S. Vaghefi, and R. Srinivasan. 2017. A guideline for successful calibration and uncertainty analysis for soil and water assessment: A review of papers from the 2016 International SWAT Conference. Water 10 (1):6. doi:10.3390/w10010006.

Agarwal, P. 2005. Ontological considerations in GIScience. *International Journal of Geographical Information Science* 19 (5):50136. doi:10.1080/ 13658810500032321.

Agrawal, A. 2002. Indigenous knowledge and the politics of classification. *International Social Science Journal* 54 (173):287–97. doi:10.1111/1468-2451.00382.

Amundson, M. A. 2002. *Yellowcake towns: Uranium mining communities in the American West*. *Mining the American West*. Boulder, CO : University Press of Colorado.

Beamer, P. I., A. J. Sugeng, M. D. Kelly, N. Lothrop, W. Klimecki, S. T. Wilkinson, and M. Loh. 2014. Use of dust fall filters as passive samplers for metal concentrations in air for communities near contaminated mine tailings. *Environmental Sciences: Processes and Impacts* 16: 1275-1281. doi:10.1039/c3em00626c.

Benson, M. H.. 2012. Mining sacred space: Law's enactment of competing ontologies in the American West. *Environment and Planning A: Economy and Space* 44 (6):1443–58. doi:10.1068/a44579.

Bogle, R., M. H. Redsteer, and J. Vogel. 2015. Field measurement and analysis of climatic factors affecting dune mobility near grand falls on the Navajo Nation, southwestern United States. *Geomorphology* 228:41–51.

Chamberlain, K. 2020. An inactive uranium mine located on a sacred mountain will finally close. NM Political Report, January 13, 2020. https://nmpoliticalreport.com/2020/01/10/an-inactive-uranium-mine-located-on-a-sacred-mountain-will-finally-close/.

Chief, K., J. F. Artiola, S. T. Wilkinson, P. Beamer, and R. M. Maier. 2016. *Understanding the Gold King Mine spill*. Tucson, AZ: University of Arizona.

deLemos J., D. Brugge, M. Cajero, M. Downs, J. L. Durant, C. M. George, S. Henio-Adeky, et al. 2009. Development of risk maps to minimize uranium exposures in the Navajo Churchrock Mining District. *Environmental Health* 8 (1):29.

[EPA] U.S. Environmental Protection Agency. 2007. Abandoned uranium mines and the Navajo Nation. Navajo Nation AUM screening assessment report and atlas with geospatial data. https://www.epa.gov/sites/production/files/2017-01/documents/navajo_nation_aum_screening_assess_report_atlas_geospatial_data-2007-08.pdf.

———. 2008. Technical report on technologically enhanced naturally occurring radioactive materials from uranium mining: Vol. 1: Mining and reclamation background. Washington, DC.

———. 2011. The legacy of abandoned uranium mines in the Grants Mineral Belt, New Mexico. USEPA Region 6. https://www.epa.gov/sites/production/files/2015-08/documents/uranium-mine-brochure.pdf.

———. 2015. Abandoned mine lands: Basic information. https://www.epa.gov/superfund/abandoned-mine-lands-basic-information-0.

———. 2016. Cleaning up abandoned uranium mines. https://www.epa.gov/navajo-nation-uranium-cleanup/cleaning-abandoned-uranium-mines.

———. 2020. Homestake Mining Co. Site profile. https://cumulis.epa.gov/supercpad/SiteProfiles/index.cfm?fuseaction=second.cleanup&id=0600816.

Erdei, E., C. S., B. Pacheco, M. Cajero, J. Lewis, and R. L. Rubin. 2019. Elevated autoimmunity in residents living near abandoned uranium mine sites on the Navajo Nation. *Journal of Autoimmunity* 99:15-23.

Ferderer, D. A. 1996. National overview of abandoned mine land sites utilizing the Minerals Availability System (MAS) and geographic information systems (GIS) technology. U.S. Geological Survey.

[GAO] 2008. U. S. Government Accountability Office. Hardrock mining: information on abandoned mines and value and coverage of financial assurances on BLM land. Washington, DC.

Gedicks, A. 1993. *The new resource wars : Native and environmental struggles against multi-national corporations*. Boston: South End Press.

Giles, A. R., H. Castleden, and A. C. Baker. 2010. "We listen to our elders. You live longer that way": Examining aquatic risk communication and water safety practices in Canada's north. *Health & Place* 16 (1): 1–9. doi:10.1016/j.healthplace.2009.05.007.

Gonzales, M., E. Erdei, J. Hoover, and J. Nash. 2018. A review of environmental epidemiology studies in southwestern and Mountain West rural minority populations. *Current Epidemiology Reports* 5 (2):101–13.

Hardesty, D. L. 1998. Power and the industrial mining community in the American West. In *Social approaches to an industrial past: the archaeology and anthropology of mining*, ed. A. B. Knapp, V. C. Pigott, and E. W. Herbert. London ; New York: Routledge, 1998.

Harmon, M.E., M. J. Campen, C. Miller, C. Shuey, M. Cajero, S. Lucas, B. Pacheco, et al. 2016. Associations of circulating oxidized LDL and conventional biomarkers of cardiovascular disease in a cross-sectional study of the Navajo population. *PloS One* 11 (3):e0143102.

Harmon, M. E,. J. Lewis, C. Miller, J. Hoover, A. S. Ali, C. Shuey, M. Cajero, et al. 2017. Residential proximity to abandoned uranium mines and serum inflammatory potential in chronically exposed Navajo communities. *Journal of Exposure Science and Environmental Epidemiology* 27 (4):365-71.

Harper, B., A. Harding, S.t Harris, and P.Berger. 2012. Subsistence exposure scenarios for tribal applications. *Human and Ecological Risk Assessment: An International Journal* 18 (4): 810–31.

Hoover, J., E. Erdei, J. Nash, and M. Gonzales. 2019. A review of metal exposure studies conducted in the rural southwestern and Mountain West Region of the United States. *Current Epidemiology Reports* 6 (1):34–49.

Hoover, J., Melissa G., Chris S., Yolanda B., and J. Lewis. 2017. Elevated arsenic and uranium concentrations in unregulated water sources on the Navajo Nation, USA. *Exposure and Health* 9 (2):113–24.

Hoover, J. H., E. Coker, Y. Barney, C. Shuey, and J. Lewis. 2018. spatial clustering of metal and metalloid mixtures in unregulated water sources on the Navajo Nation—Arizona, New Mexico, and Utah, USA. *Science of the Total Environment* 633:1667–78.

Hund, L., E. J. Bedrick, C. Miller, G. Huerta, T.Nez, S. Ramone, C. Shuey, M. Cajero, and J. Lewis. 2015. A Bayesian framework for estimating disease risk due to exposure to uranium mine and mill waste on the Navajo Nation. *Journal of the Royal Statistical Society: Series A (Statistics in Society)* 178 (4):1069–91.

Jiang, H., and J. R. Eastman. 2000. Application of fuzzy measures in multi-criteria evaluation in GIS. *International Journal of Geographical Information Science* 14 (2):173–84.

Lameman A., and T. Lynn. 2012. Distribution of uranium and other trace constituents in drain-ages downstream from reclaimed uranium mines in Cove Wash, Arizona. University of New Mexio Water Resources Professional Project Reports. https://digitalrepository.unm.edu/wr_sp/91/.

Lewis, J., J. Hoover, and D. MacKenzie. 2017. Mining and environmental health disparities in Native American communities. *Current Environmental Health Reports* 4 (2):130–41. doi: 10.1007/s40572-017-0140-5.

Lin, Y., J. Hoover, D. Beene, Z. Liu, and E. Erdei. 2020. Environmental risk mapping potential for abandoned uranium mine contamination on the Navajo Nation, USA, using a GIS-based multi-criteria decision analysis approach. *Environmental Science and Pollution Research*. (Under review).

Malczewski, J. 2006. GIS-Based multicriteria decision analysis: A survey of the literature. *International Journal of Geographical Information Science* 20 (7):703–26.

Marlow, J. 2017. Uranium contamination in the Navajo Nation: An environmental justice impact analysis | Global ecological humanities. https://sites. duke.edu/lit290s-1_02_s2017/2017/03/03/uranium-contamination-in-the-navajo-nation-an-environmental-justice-impact-analysis/.

Muller, S., S. Hemming, and D. Rigney. 2019. Indigenous sovereignties: Relational ontologies and environmental management. *Geographical Research* 57 (4):399–410. doi:10. 1111/1745-5871.12362.

Nazarro, R M. 2008. Hardrock mining: Information on abandoned mines and value and coverage of financial assurances on BLM land. U.S. Government Accounting Office GAO-08-574T.

O'Rourke, M. K., S. P. Rogan, S. Jin, and G. L. Robertson. 1999. Spatial distributions of arsenic exposure and mining communities from NHEXAS Arizona. *Journal of Exposure Analysis and Environmental Epidemiology* 9 (5):446–55. doi:10.1038/sj.jea.7500050.

Reid, G., and R. Sieber. 2019. Do geospatial ontologies perpetuate indigenous assimilation? *Progress in Human Geography*, January, 030913251882464. doi:/10.1177/0309132518824646.

Rodriguez-Freire, L., S. Avasarala, A. S. Ali, D. Agnew, J. H. Hoover, K. Artyushkova, D. E. Latta, et al. 2016. Post Gold King Mine spill investigation of metal stability in water and sediments of the Animas River watershed. *Environmental Science & Technology* 50 (21): 11539-48.

Rundstrom, R. A. 1995. GIS, indigenous peoples, and epistemological diversity. *Cartography and Geographic Information Systems* 22 (1):45–57. doi:10.1559/152304095782540564.

Sauer, C. O. 1925. *The morphology of landscape*. University of California Publications in Geography.

Sheridan, T. E. 1998. Silver shackles and copper collars: Race, class and labor in the Arizona mining industry from the eighteenth century until World War II. In *Social approaches to an industrial past: The archaeology and anthropology of mining*, ed. A. B. Knapp, V. C. Pigott, and E. W. Herbert. London; New York: Routledge, 1998.

Starr, K., and R. J. Orsi. 2000. *Rooted in barbarous soil: People, culture, and community in Gold Rush California*. Vol. 3. Univ of California Press.

Voyles, T. B. 2015. *Wastelanding : Legacies of uranium mining in Navajo Country*. Minneapolis: University of Minnesota.

Winde, F., E. Hoffmann, C. Espina, and J. Schuz. 2019. Mapping and modelling human exposure to uraniferous mine waste using a GIS-supported virtual geographic environment. *Journal of Geochemical Exploration* 204 (September):167-80. doi:/10.1016/j.gexplo.2019.05.007.

Zhang, J., and M. F. Goodchild. 2002. *Uncertainty in geographical information*. *Research monographs in geographic information systems*. London; New York: Taylor & Francis, 2002.

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COLORADO'S WESTERN SLOPE: A VIEW FROM THE OTHER SIDE OF THE DIVIDE

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The western Continental Divide of the United States splits Colorado into two regions, Eastern Colorado and Western Colorado. However, the state can be divided in many ways and the number and names of the regions are dependent upon who is defining them (climate, landscape, tourism, etc.). Three regions are generally accepted—the Front Range, the Rocky Mountains and the Western Slope (Figure 1), which relate to the continental divide and natural topographical differences (Figure 2). When most people think of Colorado, it is typically the Front Range and the Rocky Mountains. The Front Range contains the capital (Denver), all of the state's major research institutions, and the Air Force Academy. The Rocky Mountains and related ranges contain some of the best outdoor recreational opportunities in the world. However, the Western Slope has some of the most diverse physical and human attributes present in Colorado.

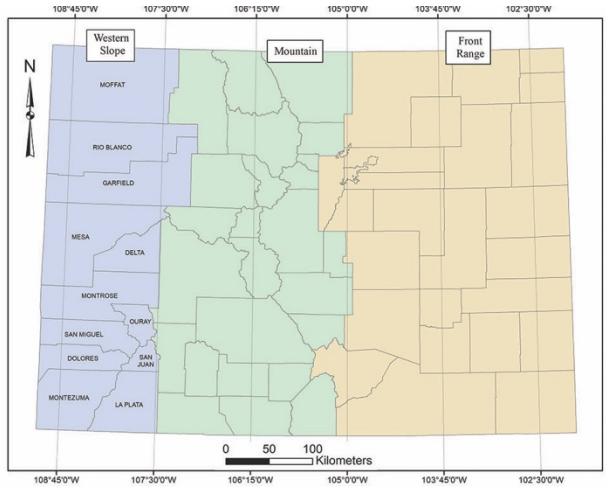

Figure 1. Regional divisions of Colorado with county boundaries, counties within the Western Slope are identified. Regional boundaries directly correspond with individual county boundaries within the region (U.S. Census Bureau 2019b).

Physical Attributes

The Western Slope includes 12 western counties. All but three share a border with Utah (Figure 1). The eastern boundary of the Western Slope almost coincides exactly at 107° 30' W longitude with the three northern most counties extending approximately 30 minutes to the east.

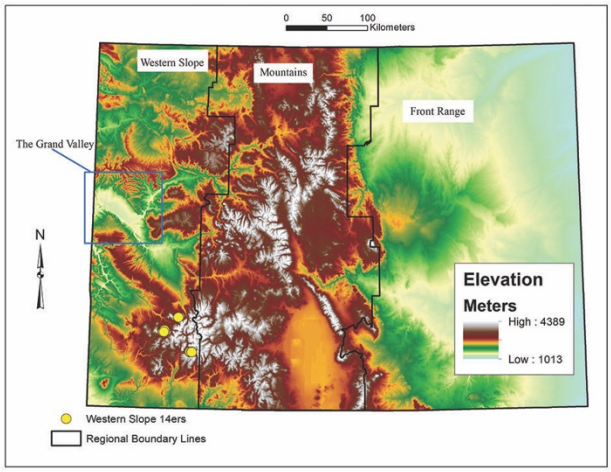

Figure 2. Regional divisions overlaid on a 90-meter digital elevation model (USGS 2015).

The diversity of the Western Slope starts with differences in relief, from the lowest elevations in the Grand Valley, where the Colorado and Gunnison Rivers converge (about 1,320 meters), to at least seven "fourteeners" in the San Juan Mountains (Mount Wilson is tallest at 4,342 meters) (Figure 2) (14ers.com 2019). The largest flattop mountain in the world (Grand Mesa) is one of three unique mountains flanking the Grand Valley (Figure 3) (Visit Grand Junction 2019). The uniqueness of this topography allows for many recreational activities but also for conservation and preservation, including 14 state parks (Colorado Parks and Wildlife 2019a), innumerable hiking trails with seven trails specific for birding (Colorado Birding Trail 2017), at least 51 State Wildlife Areas (Colorado Parks and Wildlife 2019b), and geothermal mineral pools in Ouray (Ouray Hot Springs 2020). Of significance is that the majority of the land is public (Figure 4) and home to four U.S.

Figure 3. The Grand Mesa—taken looking east from Grand Junction. Photo by the author.

National Monuments (NPS 2019a), one of which, Dinosaur National Monument, is considered to be one of the best places in the United States for viewing stars at night (NPS 2019b).

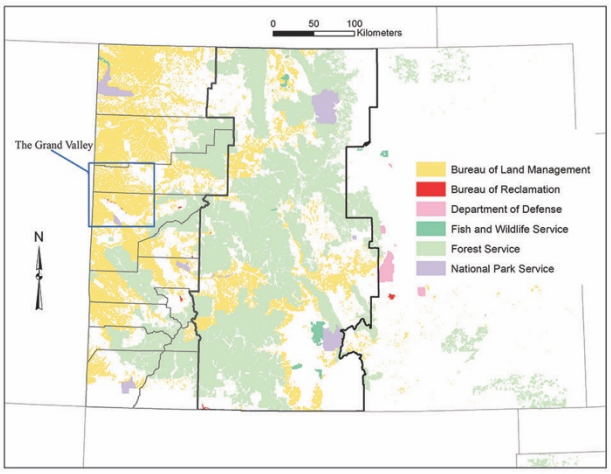

Figure 4. Public land ownership in Colorado (Esri 2019).

Topography is a major contributor to climate, especially in higher elevations. Six of the 10 climate types found in Colorado are located on the Western Slope (Figure 5) (Kottek, et al. 2006). These relate directly to topography: 1) the polar/polar tundra climate is situated on the San Juan Mountains, 2) orographic rainfall creates the arid/steppe/cold arid situated in the most western portion and the Grand Valley (as noted previously, the Grand Valley is surrounded on three sides by different ranges), and 3) the warm temperate/fully humid/warm summer occurs just to the west of the San Juan Mountains (the highest elevations in the region). The Köppen-Geiger climate classification is a very coarse scale at 0.5 degree (30 arc minutes or a cell size approximately 55 by 55 meters) (Kottek, et al. 2006), as such, the actual climate likely varies more than represented in Figure 5.

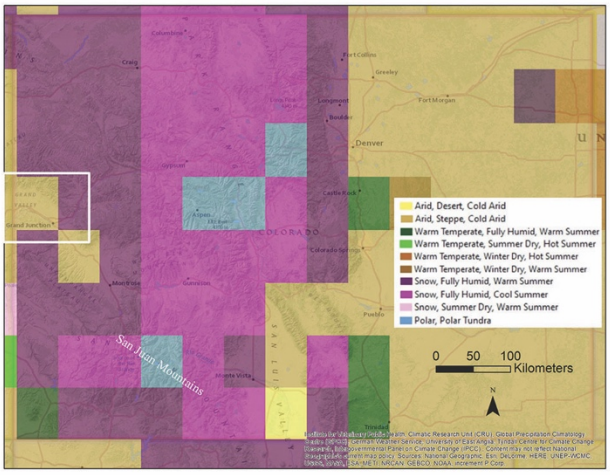

Figure 5. Climate Map of Colorado (Kottek, et al. 2006). Grand Valley is located within the white-outlined square. San Juan Mountains are located in southwestern Colorado.

Climate, topography and the biosphere contribute to the identification of ecoregions—areas where "ecosystems (and the type, quality, and quantity of environmental resources) are generally similar" (EPA 2019). Ecoregions can be defined at many different scales and identified as Levels I – IV; the higher the number, the finer the scale. Level I regions are described as "broad backdrop to the ecological mosaic of the continent" (EPA 2016) and Level II as "national and subcontinental overviews of ecological patterns" (EPA 2016). Level III provides more detail at the state level (Figure 6a), but still too coarse to explain the variations related to elevation (Figure 2), climate (Figure 5), and land cover (Figure 6b). Level IV provides the greatest detail and includes geological descriptions (Figure 6c), which is much more representative of the diversity of the Western Slope as demonstrated by Landsat 8 images of two subsections of the region (Figure 7).

The diversity in physical attributes for the Western Slope has resulted in some agricultural products that are not normally considered viable in high altitude climates—peaches, sweetcorn and wines. In the late 1970s, a hybrid sweetcorn was brought to Montrose County to replace the dwindling sugar beet industry. Montrose County was considered an appropriate place to attempt to grow sweetcorn because of the climate (hot summers and cool nights) (The Library of Congress n.d.). The sweetcorn is now

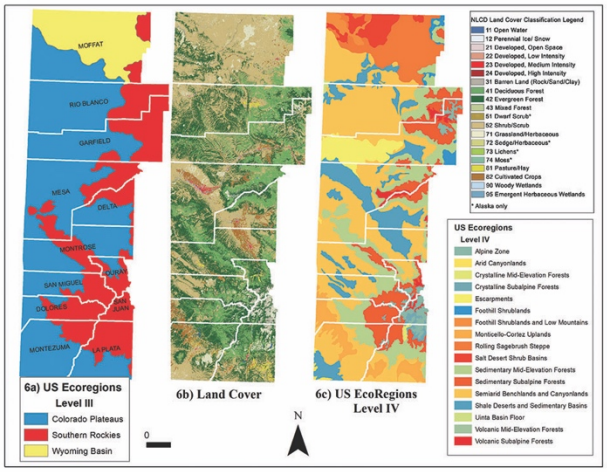

Figure 6. Ecoregions Level III (6a) and IV (6c) (U.S. EPA 2018) and Land Cover (6b) (Multi-Resolution Land Characteristics Consortium 2016).

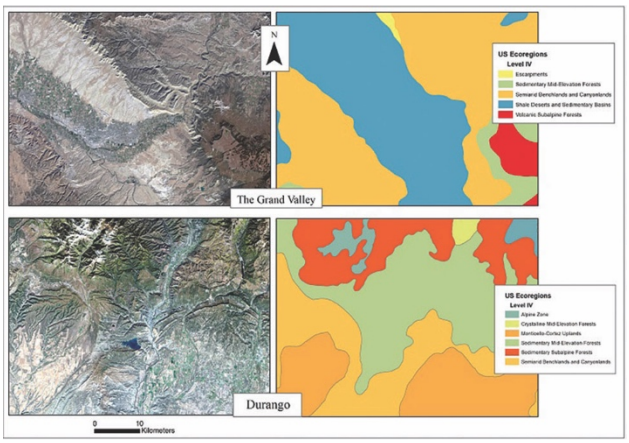

Figure 7. Landsat 8 images. Band Combination 4-3-2. Images acquired on October 11, 2019. Durango image - Path 035, Row 034; Grand Valley image - Path 035, Row 033 (USGS 2019).

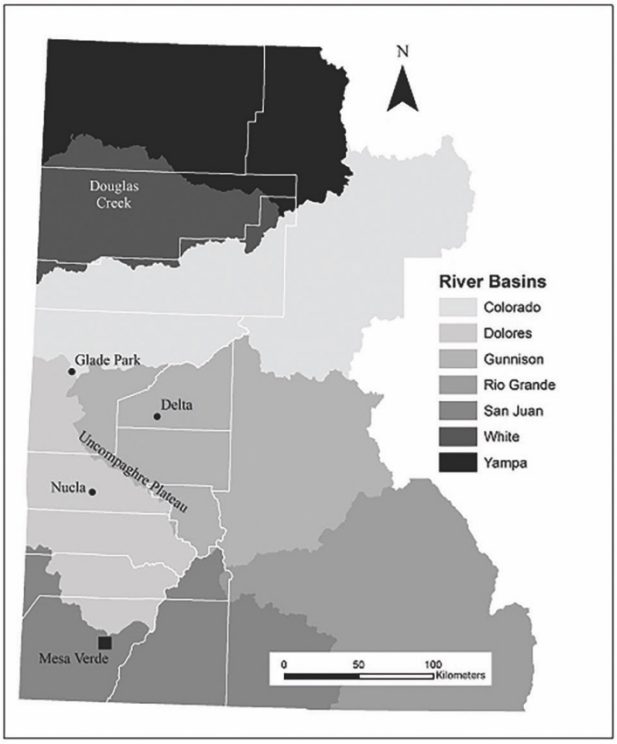

Figure 8. Reference map of all locations referenced in the section on Early Peoples of the Western Slope.

renowned, the hybrid is specifically called Olathe sweetcorn, and is celebrated by an annual festival (25 years running as of 2019) (Lofholm 2019). Likewise, Palisade Peaches, renowned throughout North America, are grown in a climate found only in the Palisade area of Mesa County, and the Peach Day festival has been celebrated for over 100 years (Palisade Colorado 2019). The Grand Valley is considered "the birthplace of Colorado wines" (History Colorado 2019). The Grand Valley American Viticultural Areas (AVA) and West Elks AVA in Delta County are the only two federally designated AVAs in Colorado. The annual wine festival, Colorado Mountain Winefest, has been held in Mesa County for the past 29 years (Colorado Mountain Winefest 2019).

Early Peoples of the Western Slope[1]

The Western Slope has been home to humans since the last Ice Age, and the archaeology of the region is as complex as its physical attributes. Prehistoric cultural manifestations present in one area may be absent or take on different aspects from basin to range or from outside of a mountain basin or in the next canyon over. This is due to the sensitive symbiosis between humans and their landscapes, for resource exploitation of course, but also for a sense of "home." Cross-cultural considerations of how ancient humans defined and used space could potentially illuminate many geospatial questions about environmental history, ecosystem conservation/rehabilitation and resource use. For example, Wilshusen (2018) notes the locations of the earliest agricultural sites in the Mesa Verde region are also the locations of his-

[1] Figure 8 is a reference map for all locations mentioned in this section

toric and modern farms. Investigating the relationships between humans and their environments is essentially inquiring about pre-historic cultural geography (Chicoine 2014).

Human occupation of western Colorado minimally began circa 13,500 BP, based on a dated hearth feature from Eagle Rockshelter, a site located on the banks of the Gunnison River near Delta (Meck 2016). This site, currently the earliest dated in the state, contains stratified evidence of foraging occupations dating from the Late Pleistocene into the Historic era. The early dates correspond to the **Paleoindian period (13,500-7500 BP)**, an era populated by highly mobile and wide-ranging foragers taking advantage of the decreased seasonality and mesic environs of the terminal Pleistocene. Paleoindians are commonly portrayed as North America's big game hunters, basing their economic lives on the procurement of large game animals such as the mammoth and bison. Eagle Rockshelter paints a different picture, however. Here, Paleoindians consistently exploited smaller game, particularly fish, for 4,000 years. The rich riparian ecosystem was clearly a major draw.

In contrast to the multiple occupations at Eagle Rockshelter, evidence from elsewhere on the Western Slope suggests Paleoindians did not intensively inhabit western Colorado. That said, the sparse archaeological record could also indicate these sites remain deeply buried. Whatever the case, the Paleoindian record is predominantly comprised of isolated artifact finds. The high country of the Rockies just to the east of the Western Slope is home to several rich Paleoindian sites (Kornfeld 2013; Morgan and Andrews 2016; Pitblado 2016; Stiger 2006). The relative paucity of Paleoindian materials from elsewhere in western Colorado is somewhat quizzical in this regard.

The end of the Pleistocene brings with it higher temperatures, less precipitation and increased seasonality. Numerous genera of animals go extinct. Human adaptations changed as ecosystems reorganized. Residential mobility was diminished and more-or-less regular seasonal rounds were established. Together these processes occur several millennia during the **Archaic Period (7500-1650 BP)**. Many archaeologists also define this period as one wherein humans adopted a "broad-spectrum" diet, establishing a more varied diet as opposed to the hunting-focus of the earlier Paleoindians. Reed and Metcalf (1999), however, note the Archaic label isn't especially meaningful on the Western Slope as people were engaged in "Archaic lifestyles" throughout prehistory and into the Historic era. Indeed, the evidence from Eagle Rockshelter shows this to be the case from the outset of human presence in the region.

The Archaic is traditionally divided into three sub-periods: Early (7500-4950 BP), Middle (4950-3450 BP), and Late (3450-1650 BP), based primarily on technological and other adaptive changes. The Early Archaic sees the continuation of mobile foraging and the establishment of seasonal rounds. The Middle and Late Archaic periods are variations on this pattern but do see a major change: the regular use of residential structures (Connor and Langdon 1987; Gooding and Shields 1985; Horn, et al. 1987). Though earlier structures are known from Colorado (Euler and Stiger 1981; Stiger 2006), they are not as numerous nor as distinct as those from later in the Archaic. Furthermore, Reed and Metcalf (1999) have identified a shift in settlement pattern from earlier occupations in the higher elevations (6400-5700 BP) to a steady increase in number of lower elevation occupations after 4000 BP, a time correlating to the evolution of near-modern environmental conditions. Thenceforth, the exploitation of lower elevations continues, peaking from 2000-1000 BP. Human settlement was responsive to the downslope migration of biota as Late Holocene temperatures decreased. Greater occupational intensity and competition for resources may have led to the increased use of residential structures at this time.

Mesoamerican cultigens appear circa 4000 BP in New Mexico and Arizona (Merrill, et al. 2009). The most important crop was maize, however, its appearance did not change ancient Southwestern economies until it became a dietary mainstay 2,000 years later. Lipe et al. (1999:135) suggest maize cultivation appears in southwestern Colorado by 3000 BP. This is reasonable given the horticulture-related dates from around the Four Corners; however, maize of this age has not yet been recovered at any site in Colorado. Instead, the earliest date from maize in the state is ca. 2,200 BP, assessed on a sample from Cottonwood Cave (Stiger and Larson 1992) located on the upland Uncompahgre Plateau near Nucla.

The tendency towards 1) increased regionalization, 2) semi-sedentary to sedentary residence, 3) reliance on or increased use of domesticates, and 4) the use of revolutionary technologies such as ceramics and the bow, typify the **Formative Period (1650-650 BP)**. Unique cultural patterns appear at this time as well: The Ancestral Puebloans of southwestern

Colorado, the Fremont in northwestern Colorado, and the Gateway Tradition (now "Gateway Phase," see Greubel 2018) between them, located in and around the Uncompahgre Plateau. Each of these evince substantial architectural investment and at least partial reliance on maize, whether received through trade or through direct cultivation. Not all peoples became agricultural, opting instead to retain their mobile foraging lifestyles (Reed and Metcalf 1999).

The Formative in the Western Slope has generated the most research relative to the other periods for several reasons. The spectacular nature of the archaeology, with its still-standing, dry-laid architecttural features, its beautifully decorated pottery, and, at least with regard to the Ancestral Puebloans, its iconic place in American cultural constructions of the Southwest, has led to sustained archaeological interest in the region since the early 1900s. Indeed, the Ancestral Puebloan sequence of the Four Corners is virtually synonymous with the prehistory of southwestern Colorado. Additionally, the younger age means sites from this era have been less impacted by the geomorphic change occurring in the region since the beginning of the Holocene, and are thus more intact.

Even though the Ancestral Puebloans are more-or-less limited to the southwestern corner of the state and are not representative of the Western Slope as a whole[2], Puebloan archaeology has heavily influenced Formative period research questions across the region. A major investigative theme has been the nature of the relationship between the Gateway and Fremont cultures and the Ancestral Puebloans (Reed and Metcalf 1999, Greubel 2018). Opinions have varied over the years, with earlier researchers contending the northern cultures represented Puebloan migrants away from their Four Corners "heartland," while more contemporary archaeologists have argued both Colorado Fremont and Gateway peoples developed autochthonously in their respective regions.

A preponderance of evidence suggests Fremont peoples are indigenous to the Great Basin, though they did maintain trade relations with Puebloan peoples. Fremont peoples moved eastward into Colorado between 1450-650 BP, settling in the Douglas Creek area where they lived until as late as 350 BP (Creasman and Scott 1987). There is also secure, though little-known, evidence for residential Fremont occupation in Glade Park, a well-watered upland area located south of the Grand Valley. Much of this evidence comes from iconic Fremont rock art (Figure 9).

Figure 9. Fremont anthropomorph (rock art) (courtesy of Curtis Martin, July 8, 2019).

The Gateway Tradition was defined as a cultural pattern of briefly occupied sites containing masonry structures reminiscent of the Fremont but using predominantly Puebloan pottery (Reed 1997). Because many key features of Puebloan and Fremont life are not in evidence at Gateway sites (Reed and Metcalf 1999), the tradition was originally argued to be indigenous to the Uncompahgre Plateau and surrounding area. A recent re-evaluation of the Gateway Tradition using ceramic sourcing techniques and a refined radiocarbon record, has reversed this initial interpretation. Now called the Gateway Phase, this construct has been re-defined as a short-lived incursion of Ancestral Puebloan people into central western Colorado between ~1050-850 BP. It may represent hunting occupations by Ancestral Puebloans away from the Four Corners, where long term occupation and land-clearing for agriculture had

[2] For more detailed information on the Ancestral Puebloans, see Colorado Council of Professional Archaeologists—namely Reed and Metcalf (1999) and Lipe, Varien and Wilshusen (1999)

likely diminished local mammalian populations (Greubel 2018).

The Aspen Tradition represents a continuation of subsistence foraging by mobile groups inhabiting areas with water and growing seasons insufficient for intensive agriculture. Like other arid areas in North America, foraging was always the primary basis of life in western Colorado. Aspen foragers did not use ceramics or establish permanent settlements. However, the overlap between Fremont settlements and Aspen Tradition sites in the Douglas Creek area may suggest they are part of one cultural system—with the foraging sites representative of hunting forays away from permanent residential settlements. One notable aspect of the Aspen Tradition is the seeming increase in the use of thermal features, leading to a surfeit of Formative period radiocarbon dates (Reed and Metcalf 1999). The reasons for this are unknown, though an increase in population is postulated. Settlement is also decidedly focused on elevations lower than 2,130 meters, continuing the trend that began in the later Archaic.

Classically, the **Protohistoric Period (650-70 BP)** is the period between the end of Formative-era agricultural economies and the "removal" of the Ute peoples in the late 19th century AD. According to Euroamerican understandings and archaeological evidence, the Ute migrated into the region circa 750-650 BP. In contrast, Ute oral histories contend they have lived in their homelands since the beginning of time. Ute archaeology is marked by the use of brush shelters, some still standing (Figure 10), coarse pottery and distinctive arrow points (Buckles 1971, Martin 2016). The use of European horses begins in earnest with the sustained presence of European populations in the early 17th century AD, and the Ute quickly adopted an equestrian lifestyle and the use of European goods (Martin 2016). Mounted Utes extended their range onto the Great Plains for the purposes of hunting bison, a practice for which we have scanty evidence on Western Slope to the 1600s.

European Settlement of the Western Slope

In 1776, Atanasio *Domínguez* and Silvestre Vélez de *Escalante, two Spanish Franciscan priests* led the earliest European exploration of the Western Slope (Museums of Western Colorado 2020). Fur traders and mountain men frequented the area through the mid-1800s and the region was explored extensively by parties led by Marcus Whitman (1842), Lt. Edward Beale and Capt. John Gunnison (1853), and Hayden Survey teams (1873-1876) (Museums of Western Colorado 2020). By the late 1870s, many lands of the Western Slope, such as the Grand Valley, were desired by European Americans moving west, leading to the continuous displacement and disenfranchisement of indigenous peoples. Plains groups were "removed" from the Front Range in the 1860s and the Ute "removed" from the Western Slope in 1881. The establishment of the Ute reservations, including two in Western Colorado, took place in the 1890s.

Settlement of the Western Slope by European Americans was limited, even during most of the 20th century because of the difficulty traversing the Continental Divide. However, with the construction of the Eisenhower-Johnson tunnels (fully completed in 1979) on Interstate 70 (Colorado Department of Transportation n.d.), this physical barrier was removed. While current populations in the Western Slope are only a small percentage (7%) of Colorado's 5.8 million people (U.S. Census Bureau 2019c), its population is growing quite rapidly and is quite diverse. In the past 50 years, the Western Slope's population has increased over 260% (Table 1).

Figure 10. Wikiup (courtesy of Chris Martin, September 13, 2017).

Table 1. Population of the Western Slope Counties 1970 – 2019.

County	Year and Population					
	1970	1980	1990	2000	2010	2019
Delta	15,286	21,225	20,980	27,834	30,952	30,953
Dolores	1,641	1,658	1,504	1,844	2,064	2,074
Garfield	14,821	22,514	29,974	43,791	56,389	59,770
La Plata	19,199	27,424	32,284	43,941	51,335	56,310
Mesa	54,374	81,530	93,145	116,255	146,717	153,207
Moffat	6,525	13,133	11,357	13,184	13,791	13,188
Montezuma	12,952	16,510	18,672	23,830	25,541	26,158
Montrose	18,366	24,352	24,423	33,432	41,277	42,214
Ouray	1,546	1,925	2,295	3,742	4,442	4,833
Rio Blanco	4,842	6,255	5,972	5,986	6,673	6,336
San Juan	831	833	745	558	699	762
San Miguel	1,949	3,192	3,653	6,594	7,359	8,191
Total	152,332	220,551	245,004	320,991	389,249	403,996

Source: U.S. Census Bureau (2017; 2018; 2019c)

Conclusion

The Western Slope region of Colorado has diversity in abundance—physical, climate, and people. The interaction of people with the environment, in the past and continuing, has created more diversity and opportunities for people living and visiting the area. It is no wonder the Western Slope of Colorado is considered one of the fast growing regions in the United States (U.S. Census 2019a).

References

14ers.com. 2019. 14ers Peak List. Accessed December 27, 2019. https://www.14ers.com/photos/photos_14ers1.php.

Chicoine, D. 2014. Archaeology and geography. In *Encyclopedia of global archaeology*, ed. C. Smith. New York: SpringerVerlag. doi:10.1007/978-3-319-51726-1_3016-1.

Colorado Birding Trail. 2017. Western Colorado The Trails. Accessed December 28, 2019. https://coloradobirdingtrail.com/the-trails/western-colorado/.

Colorado Department of Transportation. n.d. Travel Center: About the Eisenhower Tunnel. Accessed January 12, 2020. https://www.codot.gov/travel/eisenhower-tunnel/description.html.

Colorado Mountain Winefest. 2019. Accessed December 30, 2019. https://coloradowinefest.com/.

Colorado Parks and Wildlife. 2019a. State Parks. Accessed December 30, 2019. https://cpw.state.co.us/placestogo/parks.

———. 2019b. State Wildlife Area Map. Accessed December 29, 2019. https://cpw.state.co.us/placestogo/parks/Pages/WildlifeAreaMap.aspx.

Conner, C. E. and D. L. Langdon. 1987. Battlement Mesa cultural resources study. Report prepared by Grand River Institute for Battlement Mesa, Inc., Colorado Historical Society, Denver.

Creasman, S. D. and L. J. Scott. 1987. Texas Creek Overlook: Evidence for Late Fremont (post AD 1200) occupation in northwest Colorado. *Southwestern Lore* 53 (4):1-16.

[EPA] U.S. Environmental Protection Agency. 2016. Ecoregions of North America. Accessed December 27, 2019. https://www.epa.gov/eco-research/ecoregions-north-america.

———. 2018. Ecoregions. Accessed December 29, 2019. https://www.epa.gov/eco-research/ecoregions.

Esri. 2019. USA Federal Lands Map ArcGIS Online. Accessed December 28, 2019. https://www.arcgis.com/home/item.html?id=8047eda3656e4241b75463a5451ba9e2.

Euler, R. T. and M. A. Stiger. 1981. 1978 Test excavations at five archaeological sites in Curecanti National Recreation Area Intermountain Colorado, Midwest Archeological Center, Lincoln Nebraska.

Gooding, J. D. and W. L. Shields. 1985. Sisyphus Shelter. Highway Salvage Series 50, Cultural Resources Series 18, Colorado Department of Transportation, Denver.

Greubel, R. A. 2018. Recent developments in Gateway Phase research. *Reviews in Colorado Archaeology* 1 (3):41-68.

History Colorado. 2019. Historic wineries Colorado. Accessed December 31, 2019. https://www.historycolorado.org/story/going-places/2019/05/17/historic-wineries-colorado.

Horn, J. C., A. D. Reed and S. M. Chandler. 1987. Archaeological investigations at the Indian Creek Site, 5ME1373: A stratified archaic site in Mesa County, Colorado. Bureau of Land Management, Grand Junction Colorado.

Kornfeld, M. 2013. *The first Rocky Mountaineers: Coloradoans before Colorado*. Salt Lake City: University of Utah Press.

Kottek, M., J. Grieser, C. Beck, B. Rudolf, and F. Rubel. 2006. World map of the Köppen-Geiger climate classification updated. *Meteorologische Zeitschrift* (15**)** 259-263. doi:10.1127/0941-2948/2006/0130.

Lipe, W. D., M. D. Varien, and R. H. Wilshusen. 1999. *Colorado prehistory: A context for the southern Colorado River Basin*. Colorado Council of Professional Archaeologists, Denver.

Lofholm, N. 2019. Sweetcorn put Olathe on the map, but seeds of economic revival didn't take. *Colorado Sun*. July 24. Accessed December 31, 2019. https://coloradosun.com/2019/07/24/olathe-sweet-corn-economic-decline/.

Martin, C. 2016. *Ephemeral bounty: Wickiups, trade goods and the final years of the autonomous Ute*. Salt Lake City: University of Utah Press.

Meck, T. 2016. Eagle Rockshelter offers new insights into Paleoindian Culture. *Delta County Independent*. Accessed January 8, 2020. https://www.deltacountyindependent.com/news/north-fork/eagle-rock-shelter-offers-new-insights-into-paleo-indian-culture/article_f452c01c-baab-5ab8-8b8b-66855c80db22.html.

Merrill, W. L., R. J. Hard, J. B. Mabry, G. J. Fritz, K. R. Adams, J. R. Roney, and A. C. MacWilliams. 2009. The diffusion of maize to the southwestern United States and its impact. *Proceedings of the National Academy of Sciences* 106 (50):21019-21026.

Morgan, B. M. and B. N. Andrews. 2016. Folsom stone tool distribution at the Mountaineer Block C Dwelling: Indoor and outdoor spaces as activity areas. *PaleoAmerica* 2 (2):179-187. doi:10.1080/20555563.2016.1174567.

Museum of Western Colorado. 2020. History of the Grand Valley. Accessed January 12, 2020. https://museumofwesternco.com/learn/history-of-grand-valley/grand-junction-history/.

Multi-Resolution Land Characteristics Consortium. 2016. National Land Cover Data. Downloaded December 1, 2019. https://www.mrlc.gov/data?f%5B0%5D=category%3Aland%20cover.

[NPS] National Park Service. 2019. National Park Service Archeology Program. U.S. Department of Interior. Accessed December 27, 2019. https://www.nps.gov/archeology/sites/antiquities/monumentslist.htm.

———. 2019. National Park Service, Dinosaur National Monument. Accessed December 27, 2019. https://www.nps.gov/dino/planyourvisit/stargazing.htm.

Ouray Hot Springs. 2020. Accessed January 12, 2020. https://ourayhotsprings.com/.

Palisade Colorado. 2019. Orchards & Farms. Accessed December 30, 2019. https://visitpalisade.com/orchards-and-farms/.

Pitblado, B. L. 2016. Paleoindian archaeology of the Upper Gunnison Basin, Colorado Rocky Mountains. *North American Archaeologist* 37 (1): 20-60.

Reed, A. D. 1997. The Gateway Tradition: A formative stage culture unit for east-central Utah and west-central Colorado. *Southwestern Lore* 63 (2): 19-26.

Reed, A. D. and M. D. Metcalf. 1999. *Colorado prehistory: A context for the northern Colorado River Basin.* Colorado Council of Professional Archaeologists, Denver.

Stiger, M. A. 2006. A Folsom structure in the Colorado Mountains. *American Antiquity* 71 (2): 321-351.

Stiger, M. A. and M. Larson. 1992. A radiocarbon date from the Cottonwood Cave Corn Cache and problems interpreting the origins of farming in western Colorado. *Southwestern Lore* 58 (2):26-36.

The Library of Congress. n.d. Local Legacies/Colorado/Olathe Sweet Corn Festival. Accessed December 31, 2019. http://memory.loc.gov/diglib/legacies/loc.afc.afc-legacies.200002773/.

U. S. Census Bureau. 2017. Characteristics of the population: General social and economic

characteristics: 1980-1983. Report Number PC80-1 series, Washington, DC.

———. 2018. 1990 Census of population: General population characteristics: Colorado 1992. Report Number CP-1, Washington, DC. https://www2.census.gov/library/publications/decennial/1990/cp-1/cp-1-7.pdf.

———. 2019a. Percent population change by county and municipio, 2017-2018. Accessed April 18, 2019. https://www.census.gov/library/visualizations/2019/comm/percent-pop-changcounty.html.

———. 2019b. Tiger/Line Shapefiles. Downloaded December 1, 2019. https://www.census.gov/geographies/mapping-files/time-series/geo/tiger-line-file.html.

———. 2019c. Quick facts. Accessed December 27, 2019. https://www.census.gov/quickfacts/fact/table/US/PST045219.

[USGS] United States Geological Survey. 2015. U.S. National Map downloads elevation products. Downloaded on December 1, 2019. https://viewer.nationalmap.gov/basic/.

———. 2019. Earth Explorer – Landsat Collection 1 Level 1. Downloaded December 31, 2019. https://earthexplorer.usgs.gov/.

Visit Grand Junction. 2019. Grand Mesa. Accessed December 29, 2019. https://www.visitgrandjunction.com/areas/grand-mesa.

Wilshusen, R. H. 2018. How agriculture took hold in the Mesa Verde Region: A review of recent research on the Late Basketmaker-Early Pueblo Periods (AD 500-920). *Reviews in Colorado Archaeology* 1 (4):69-95.

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DEVELOPMENT AND LAND-USE CHANGE IN THE ROCKY MOUNTAIN WEST

Plains Conservation Center, Aurora, Colorado. Photo by Michael Keables.

THE MAKING OF A MEGAREGION: REGIONAL DEVELOPMENT AND THE LANDSCAPES OF COLORADO'S FRONT RANGE URBAN CORRIDOR

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Introduction

The Colorado Front Range Urban Corridor (CFRUC), and Colorado more generally, with strong economic growth and easy access to recreational resources that contribute to a high quality of life, appears attractive to immigration. The two largest cities in the CFRUC, Denver and Colorado Springs, have been continuously ranked among the top five of the most desirable cities among Americans surveyed by *U.S. News & World Report* since 2005, where desirability is linked to employment, education, and recreation opportunities. The Colorado State Demography Office projects that the state population, which was 5,696,000 in 2018, could reach 8.1 million by 2050. This increase will likely have disproportionate impact on the CFRUC. This corridor consists of 25 populous municipalities, each with 2016 estimated population ranging from 30,000 to 700,000, and include major cities such as Fort Collins, Greeley, Longmont, Boulder, Denver, Aurora, Colorado Springs, and Pueblo (Figure 1). The U.S.A. Regional Plan Association, an independent New York-based non-profit planning organization, identified CFRUC as a part of the Front Range megaregion, one of 11 megaregions in the country. The Front Range megaregion extends from Cheyenne, Wyoming to Albuquerque, New Mexico (Figure 2). Megaregions are defined using five major categories of relationships which together define a common interest in order to form the basis for policy decisions. These categories include (1) environmental systems and topography, (2) infrastructure systems, (3) economic linkages, (4) settlement patterns and land use, and (5) shared culture and history (Regional Plan Association 2014). The development of these megaregions has in part been influenced by the growth of transportation routes and economic opportunities, but also by shared environmental conditions, culture and history (Fishman 2007; Todorovich 2009; America2050.org). The anticipated growth in these megaregions presents development opportunities

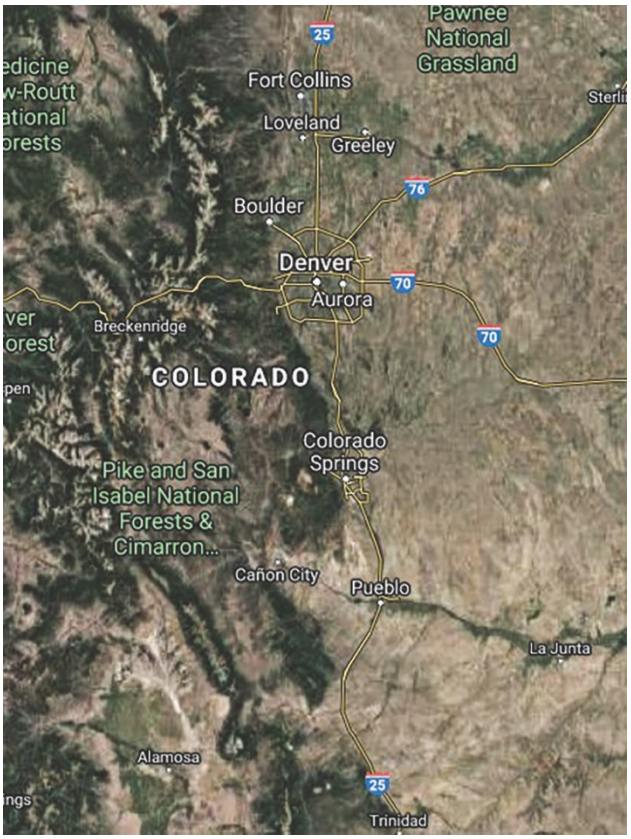

Figure 1. Major cities along the Colorado Front Range Urban Corridor.

while also producing a myriad of challenges associated with supporting existing and anticipated growth in population. For example, megaregions cross multiple socio-political boundaries which necessitates collaboration across governance entities, yet to date many collaborative efforts in these regions have been ad hoc (Todorovich 2009).

The National Committee for America 2050 promotes the development of improved collaborative planning and policy strategies to support the growth of megaregions. The CRFUC is part of the smallest, but one of the fastest growing, megaregions (America2050.org). In this article, we present a brief

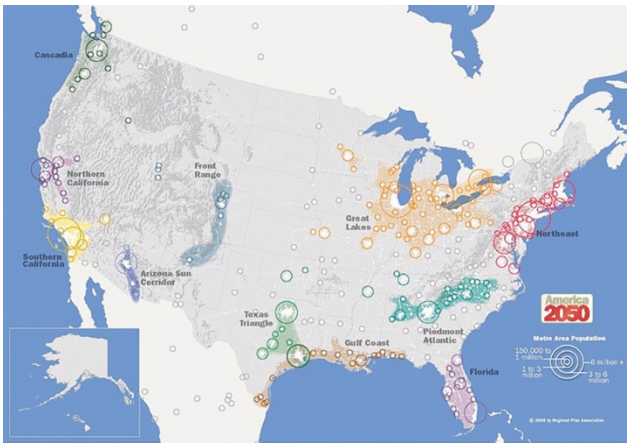

Figure 2. The Front Range—which includes CFRUC—is one among 11 megaregions of the country by 2050 (Regional Plan Association, 2014).

overview of the pre-1970 history in Colorado, followed by a portrait of regional growth and change in the CFRUC's since 1970. Understanding the CFRUC historical changes in settlements and regional development as well as their impacts can serve to inform planning for future growth. The role of these changes in shaping the current environmental and cultural contexts for the region offers an interesting and useful consideration as these spaces begin to address the opportunities and challenges of a megaregion status.

CFRUC Prior 1970: A Deep Root

Prior to 1970, the CFRUC experienced development booms and busts. The era of gold and silver mining (1850s-1890s) brought hundreds of thousands newcomers to the state, rushing for well-known mountain mining towns such as Leadville (100 driving miles west of Denver) and Cripple Creek (45 driving miles west of Colorado Springs). Figure 3 depicts the Colorado mineral and coal mining belt of 1800s and early 1900s. This era mapped the region as a vital part of the U.S. railroad network. Denver, whose population was 287,861 in 1930 (compared to 35,629 in 1890), served as a central locality for much of the western U.S., providing services and manufacturing in support of the mining industry. Pueblo was the second largest town in 1930 with a population of 50,096 and was known for its ties to the Colorado Fuel and Iron (CF&I) Company and was the headquarters for the Pacific Union railroad system. Contrasting the blue-collar nature of Pueblo, Colorado Springs, home to 33,237 in 1930, was a luxury resort town catering to wealthy mining company owners. The city's luxury Broadmoor resort, Garden of the Gods, Manitou Springs hot springs, and Pikes Peak scenic settings provided an escape from other industrial and mining spaces in the state.

Figure 3. Colorado mineral and coal mining belt of 1800s and early 1900s (Colorado Historical Maps, University of Colorado Boulder).

The region was also well-known for its agricultural achievements (Abbott et al. 2013). Cattle ranches were once among the best in the country for both quality and quantity of the production, given the free and nutritious grasses on the unsettled plains (Abbott et al. 2013). The sugar beet industry blossomed with the first factory established in Grand Junction (roughly 243 driving miles west of Denver) in 1899 and continued to serve as a productive agricultural industry until the mid-twentieth century. Successful farming and ranching endeavors shaped Colorado's history despite the challenges of drought. Water had been, and continues to be, a limiting factor to growth and development in Colorado. Multiple rivers originate in, or intersect with, the state but much of the water flows out of state, either to the Western Slope of the Continental Divide or east to Kansas and Nebraska. Coloradans have worked out a complex rights-based water solution to support impressive irrigation systems and river conversion, erasing the image of a Great American Desert to offer

several Great Plains garden spots in towns like Greeley, Fort Collins, and Pueblo (Abbott et al. 2013).

World War II (1941-1945) yielded an opportunity for economic growth for Coloradans to access large quantities of federal defense funding. Even before the war started, President Roosevelt began building up the nation's defense in the late 1930s on Colorado land, with major defense establishments located along the CFRUC (Abbott et al. 2013). These include Fitzsimons Army Hospital near Denver (later becoming a part of the University of Colorado Denver Anschutz Medical Campus), Lowry Air Force Base near Denver, Camp Carson near Colorado Springs (later becoming Fort Carson), Peterson Air Force Base and Ent Air Force Base in Colorado Springs. Pueblo also drew federal attention because it was well connected by railroad and was the home to Colorado Fuel and Iron (CF&I). During the peak of WWII, CF&I increased its running capacity to 250% in steel production to contribute to ally victory (Abbott et al. 2013). The state benefited from engagement in WWII, and war related industry and defense—a trend that continued into the Cold War and remains a central part of the current landscape.

In what might appear to be a contradictory development to the state's engagement in national defense upon first glance, Colorado also developed a robust tourist industry. The development of a well-connected railroad system coupled with breath-taking scenery has drawn eastern vacationers to the Rockies. The first 14-hour Chicago-Denver train carrying skiers to the region in 1934 can be marked as the start of the skiing industry. Despite this early start, the skiing industry didn't experience a boom until the latter half of twentieth century together with increases in reasonable airfares and interstate highway connectivity. Colorado's moderate climate and striking physical geography facilitated a reputation in the minds of city dwellers as a state in which you could escape to nature (Kendall 2002). The tourism surge was further enabled by the "Era of Federal Spending" after WWII, which benefited the growth of infrastructure and tourist attractions (Kendall 2002).

CFRUC 1970-onward: Controlled Growth and Resource Preservation

During the second half of the twentieth century and beginning of the twenty-first century, the region continued to grow. However, since the 1970's, Coloradans have become increasingly aware of growth-related matters such as urban sprawl, conservation of open space, air and water pollution, the danger of radioactivity, the merits of renewable energy, challenges of inequality, preservation of resources and wilderness, survival of endangered species, protection of scenery and historic structures. Such issues continue to emerge as the state attracts new residents, in particular younger generations—Millennials and Generation Z—who identify Colorado as an attractive state to migrate to (Svaldi 2019).

Easy Access: Highway and Airlines Development

The transportation focus for the region stemming from being a railroad hub during the second half of the nineteenth century, continued as Colorado became automobile-focused and an airline hub. The development of a dense highway network began in the first half of 1900s when federal funding helped to pave highways around major military facilities (Figure 4). In the 1970s, highway I-70 connecting the CFRUC to western Colorado was extended by the opening of the Eisenhower and Edwin Johnson Tunnel, 57 driving miles west of Denver. This opened the era of western Colorado development and easy access to natural recreational resources, further increasing the desirability of the CFRUC. By 1980s, Colorado had a well-connected automobile network along the Front Range and into mountain towns and resorts.

Beyond automobile access, Colorado has also become a central hub for international and domestic airlines. From 1929-1995, Denver's Stapleton Airport served as a major airport in the western United States and the primary airport of the CFRUC (Abbott et al. 2013). The Denver International Airport, which replaced the Stapleton Airport in 1995, has served as an international airport in the western United States and a major hub within U.S. domestic's airline network. Settled on 33,531 acres, it is the largest airport in North America by total land area and the second largest in the world (City & County of Denver Department of Aviation 2017). As of 2018, the airport is the 20th busiest airport in the world and the fifth busiest in the country. It is also the fourth largest hub for United Airlines, the largest hub for Frontier Airlines, and a main operating base for Southwest Airlines (City & County of Denver Department of Aviation 2017).

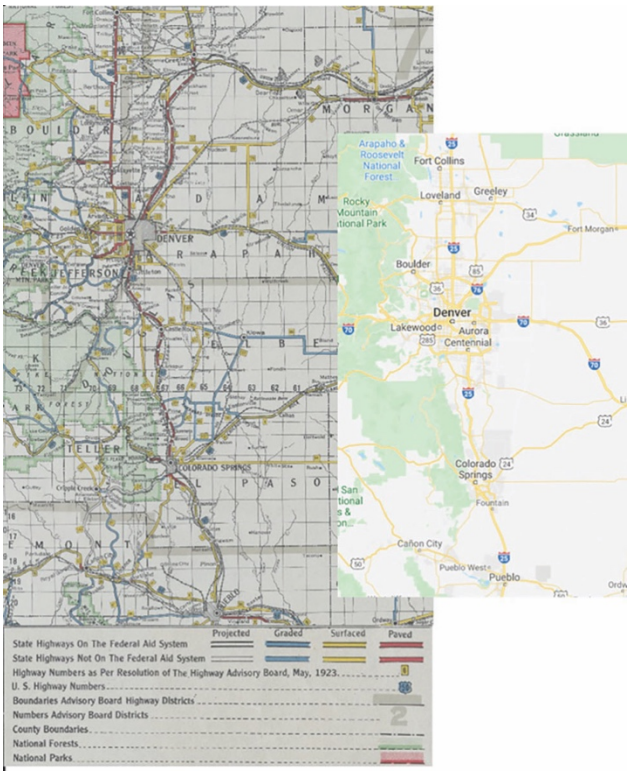

Figure 4. Colorado highway and road system in 1927 (left) and 2018 (right) (Colorado Historical Maps, University of Colorado Boulder; Google 2020).

Multi-dimensional Appeal: Economic-Education-Recreation Settings

During 1970s-2000s, despite bankruptcy declaration of some 1950s-1960s mining and nuclear weapon giants like Colorado Fuel and Iron, Gates, The Rocky Flats nuclear weapons facility, or Rocky Mountain Aresnal's chemical weapon factory, the state's economy quickly engaged with aerospace and defense, brewing and entertainment industry, and tourism. *U.S. News & World Report* in 2018 ranked Colorado as #1 in Economic (based on business environment, unemployment, and growth rate), #12 in Healthcare (based on health care access, heath care quality, and public heath) and #11 in Education (based on pre-K-12 and higher education); the rankings remain unchanged until 2020 (*U.S. News* 2019). According to the Colorado Department of Labor and Employment and the U.S. Bureau of Labor Statistics, workers in the State of Colorado had an average hourly wage of $26.84 in 2018, more than 7% above the U.S. average of $24.98; the statewide median hourly wage for all covered employment was $20.34 compared to the U.S. median of $18.58. The state's unemployment rate in 2018 is 2.7%, compared to the national 4%. In 2018, 49% of Coloradans are college educated (*U.S. News* 2019). The state takes pride in its number of highly ranked colleges by U.S. News in 2019, including Colorado College (in Colorado Springs, #27 in National Liberal Arts Colleges), U.S. Air Force Academy (in Colorado Springs, #39 in National Liberal Arts Colleges), School of Mines (in Golden, #84 in National Universities), University of Denver (#97 in National Universities), University of Colorado Boulder (#104 in National Universities). The highly educated population has shaped a distinct cultural and social setting along the CFRUC where music, art, and science play key entertainment roles in local communities in the CFRUC.

Aerospace and Defense Industry

During the second half of the 21st century, Colorado made more rockets than any other state (Abbott et al. 2013), in part due to suitable environmental conditions for the testing of solar flares. Most of the research and manufacturing facilities are within the CFRUC. The *Denver Post* in 2003 announced the aerospace industry had brought 110,000 jobs to the state and made up 8% of its economy (*Denver Post* 2018). The rocket manufacturing industry in Colorado can be dated back in 1941 when the Boulder-based Ball Brothers begun manufacturing rocket control devices. The Glen L. Martin Company —which later evolved to Lockheed Martin Space System in 1994—firmly shaped the economic and social landscape along the CFRUC through land acquisition (e.g., a 7000-acre track 12 miles southwest of Denver) and space science developments such as the Martin's Magellan spacecraft which travelled to Venus and collected radar imaging in 1990.

Entertainment and Recreation

The CFRUC holds the title as the country's "Napa Valley for beer connoisseurs" given by the *Seattle Times* (Noel, 2010). The state is the largest beer producer and the central hub to two large breweries—Coors which later became Miller-Coors, and Anheuser-Busch (Abbott et al. 2013). Beyond production quantity, an identity associated with craft beer has been nurtured. Colorado, along with the West Coast, is identified by geographers as the "hearth" for the microbrewery movement, which now extends to a nationwide trend—successful in part due to its ability to reconnect people to local places (Schnell and Reese 2003).

Culture and entertainment have also been influenced by television, which first came to Colorado in 1952. Thirty years later, in the 1980s, Denver became the cable capital of the country and home to the "father of cable television" Bill Daniels, as well as of various cable moguls such as Bob Magness, founder of Tele-Communications, Inc. (TCI) and John Malone, chief executive officer of TCI for 24 years. Dish Network Corporation, a Denver based company, was founded and has been owned by Coloradans since 1980s. The CFRUC is also home to several nationally renowned and local sport teams. These include football (Denver's Broncos), baseball (Colorado Springs's Sky Sox and Denver's Colorado Rockies), basketball (Denver's Nuggets), and hockey (the NHL and two-time Stanley cup champion Colorado Avalanche). In many ways, this diversity in local sports teams offers potential entertainment for diverse audiences.

Colorado tourism has significantly increased in recent decades. From 2009-2017, the number of visitors to the state increased by 41%, exceeding the national average increase of 20% (Colorado Tourism Office). This led to increased exposure to the amenities the state offers, while also creating job opportunities. Since the development of Aspen, a mountain resort 3.5 driving hours west of Denver, winter sports have received much attention. However, natural and anthropogenic attractions such as Rocky Mountain National Park and Mesa Verde National Park contribute to the portrayal of Colorado as a year-round tourist destination. This portrayal attracts short-term visitors and has brought an influx of second home buyers, and permanent residents. This mixture of immigration contributes to increasing growth in the CFRUC while also impacting more rural spaces, further connecting the CFRUC to the western parts of the state.

Further complicating the sometimes-dichotomous dialogue of tourism and environmental presser-vation are external factors such as climate change. Climate change has placed increasing pressure on ski resorts due to increased variability in snow conditions but has also had significant impact on non-winter tourist attractions such as national and state parks. For example, in 2006, large rainfall events caused $400,000 loss of profits for Colorado State Parks (Alvord et al. 2008). Such threats to the tourism industry have been buffered by 2012 state legislation which added recreational marijuana to the tourism landscape. Sales of recreational marijuana are anticipated to reach $22 billion by 2020, and as of 2015 approximately half of all visitors to Colorado were aware of the legalization of marijuana and reported being influenced by this newly added Colorado characteristic (Blevins 2015; Hudleston 2016).

Population Growth, Increase Diversity, and Changing Urban Patterns

Economic prosperity, pleasant climate, and high quality of life have drawn more than 3 million newcomers to the state since 1970. Highway networks have contributed significantly to shaping the Front Range urban patterns during 1970-2018. At the beginning of 1970s, CFRUC had established substantial but isolated downtown cores. The highway network connecting north to south and east to west facilitated travel and access out of these downtown cores. This led to the emergence of an urban sprawl pattern, and to a rapid reduction in the wide-open space once easily observed along the Front Range (Figure 5). In Denver, many newcomers lived near interstate highways, sparking suburban growth and boosting the population in Denver's satellite cities like Arvada (population 106,433 in 2010) Aurora (325,078), Lakewood (142,980) Thornton (118,772), and Westminster (106,114) (Figure 6). Douglas County, between Denver's southern suburbs and Colorado Springs, grew from 60,391 in 1990 to 335,339 in 2017. Arapahoe County and the City of Aurora welcomed nearly 480,000 newcomers during 1970-2017. West of downtown Denver, a 1950s farm town transformed into the city of Bloomfield, which as of 2017 had a population of 68,917. The counties with the fastest growth include those to the northeast, east, and south of Denver. The population of Colorado Springs and its suburbs increased by more than 450,000 during these years.

Along with growth in population, Colorado cities experienced increasing diversity (Figure 7). Among 5.7 million population counted in 2018, roughly 69% (about 7% higher than national average) are Caucasian, 21% (4% higher) are Hispanic, 4% (8.5% lower) are African Americans, and 3% (2.3% lower) are Asian. The majority of Hispanic Americans, African Americans, and Asian Americans are concentrated in major cities along the CFRUC. Diversity in the CFRUC has been influenced by a range of factors, extending beyond the focus of this chapter. For

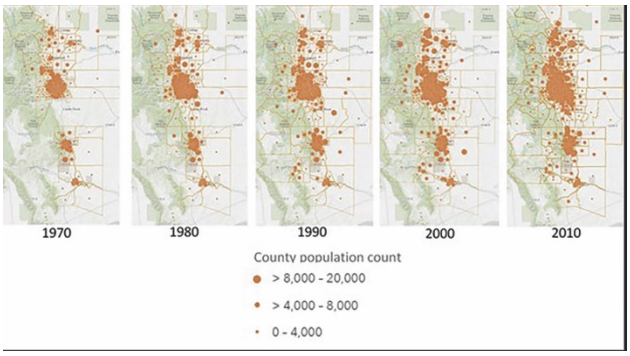

Figure 5. CFRUC county population growth projecting an urban sprawl pattern during 1970-2010. Sources: U.S. Census 1970 - 2010 and American Community Survey 5-year estimated 2013-2018.

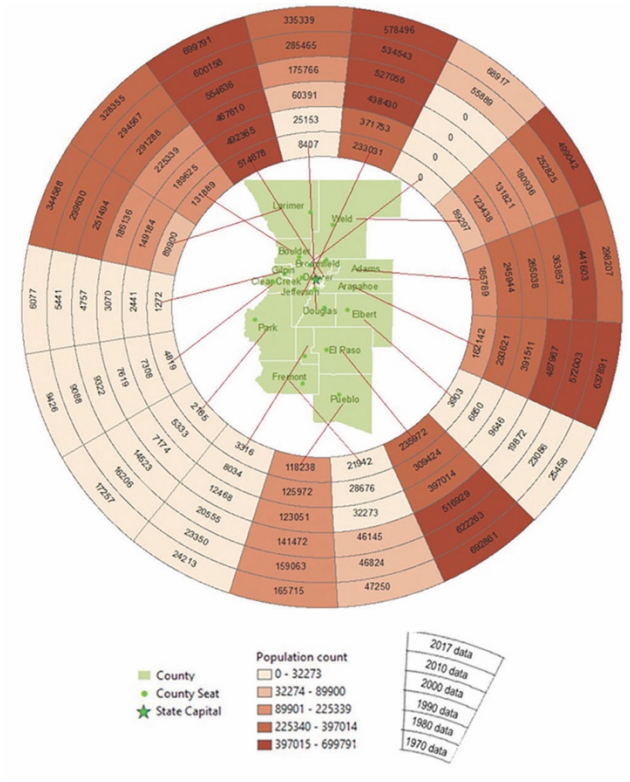

Figure 7. CFRUC county population race composition changes from 1980 to 2017. Sources: U.S. Census 1970 - 2010 and American Community Survey 5-year estimated 2013-2018.

Figure 6. CFRUC county population changes from 1970 to 2017. Sources: U.S. Census 1970 - 2010 and American Community Survey 5-year estimated 2013-2018.

example, for the high proportion of Hispanics in the state, these include but are not limited to changes to the Mexican border in response to the Treaty of Guadalupe Hidalgo and various eras of migration throughout the state's history.

Recent Landscape Shifts

Changes in the landscape can serve as physical indications of changes in the population or in the preferences of the population. Such changes are often complex and occur at multiple scales. Here we present a brief example of some of the landscape changes in the recent history of the CFRUC. The patterns shown here provide a representation of the recent ways in which human settlements in the CFRUC have modified the physical landscape. These recent landscape patterns can serve as a foundation for collaborative planning and policy-making regarding future potential changes in this burgeoning part of the megaregion.

The data utilized to provide this illustration of landscape change includes the National Land Cover Database, which offers a 16-class land cover

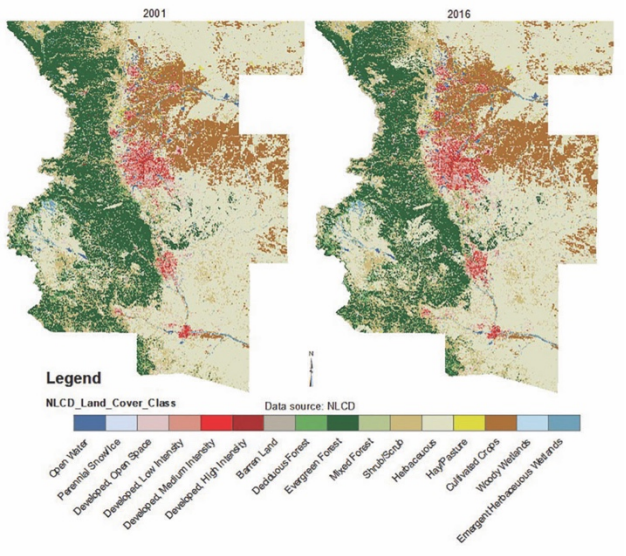

Figure 8. Broad landscape patterns along the CFRUC in 2001 and 2016 characterized through the National Land Cover Dataset.

classification based on 30-meter resolution satellite imagery from the Landsat Program, along with high resolution aerial imagery from the National Agriculture Imagery Program (NAIP). Figure 8 shows the land cover classification of the CFRUC landscape in 2001 and 2016. The majority of the landscape (>50%) at both points in time is covered by land covers and uses associated with Colorado's recreation identity. These include various forms of forest, water, and open space. Change in land cover, which is likely associated with increasing population in the CFRUC, can be seen in the increases of developed open space, and low-medium- high intensity development. In particular, increases in the development classes occur along the I-70 corridor in Denver heading eastward, northeastern portions of Colorado Springs, and a densification of these classes in and near of Greeley and Pueblo. Changes in landscape patterns across the CFRUC can be broadly examined through the use of national land cover datasets, but high-resolution aerial imagery supports additional examples of patterns of landscape change within the CFRUC. Figure 9 utilizes this data to contrast landscape patterns between 2004 and 2016. The examples shown in Figure 9 highlight recent landscape changes in Denver, Colorado Springs, and Pueblo. Of note in these examples is the change of bare land and grass-land areas to built landscapes of varying densities. The examples highlight ways in which changing demographics may influence the landscape. As part of the Front Range megaregion,

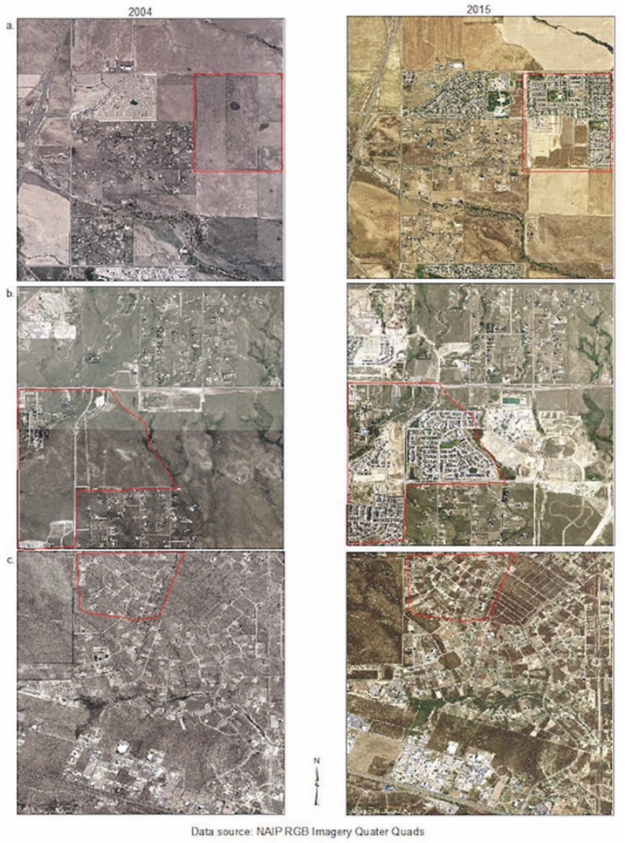

Figure 9. Examples of recent changes in the landscapes of (a) Denver, (b) Colorado Springs, and (c) Pueblo. The changes from bare land, grassland, and shrubland to built spaces of varying densities is highlight in the red polygons overlaying the NAIP imagery form 2004 and 2015.

the CFRUC is expected to experience continued growth and this will likely result in future landscape changes. The diversity in identities of the CFRUC, e.g., a space for economic development and recreation, could yield interesting and complex physical landscape change as the area seeks to meet the multiple needs of the changing population.

Looking forward

Megaregions can anticipate further growth, opportunity, and challenges. The CFRUC has managed to intertwine a blend of industry, agriculture, defense, and tourism into a unique Colorado identity that is tightly connected to the environmental characteristics of the state and its people. This yields a CFRUC region that is appealing to many and particularly to those seeking a balance between economic opportunity and a high quality of life. The history of development and population growth in Colorado has

contributed to the formation of a setting that is seen to present this balance. The portrait of growth and change since 1970 presented here shows a diversification in population coupled with changes in the landscape that would be expected with a future increasing population. Future growth plans for the region will need to consider how to continue meeting the desires of diverse and growing populations while continuing to foster an evolving Colorado character.

References

Abbott, C., S. Leonard, and T. Noel. 2013. *Colorado: A history of the Centennial State.* 5th ed. Boulder, CO: Colorado Associated University Press.

Alvord, C., P. Long, R. Pulwarty, and B. Udall. 2008. Climate and tourism on the Colorado Plateau. *Bulletin of the American Meteorological Society*, 89 (5): 673-675.

Benson, M., D. Smith, and C. Ubbelohde. 2015. *A Colorado history*. 10th ed. Portland, OR: WestWinds Press.

Blevins, J. 2015. Marijuana has huge influence on Colorado tourism, state survey says. *Denver Post*, December 9. Accessed January 8, 2020. http://www.denverpost.com/2015/12/09/marijuana-has-huge-influence-on-colorado-tourism-state-survey-says-2/.

Colorado Department of Labor and Employment. 2019. Accessed January 8, 2020. https://www.colorado.gov/pacific/cdle/news/colorado-occupational-employment-and-wages-2018.

Denver International Airport Total Operations and Traffic. 2017. Passenger Traffic Reports. City & County of Denver Department of Aviation. Accessed January 9, 2020. https://www.flydenver.com/about/financials/passenger_traffic.

Dimock, M. 2019. Defining generations: Where Millennials end and Generation Z begins. Pew Research Center. Accessed February 14, 2020. https://www.pewresearch.org/fact-tank/2019/01/17/where-millennials-end-and-generation-z-begins/.

Fishman, R. 2007. 1808-1908-2008: National planning for America, America 2050: Framing papers for the Rockefeller Foundation Global Urban Summit, Regional Plan Association, New York, NY.

Google. 2020. Map of Colorado. Accessed February 5, 2020. https://www.google.com.

Gottman, J. 1961. *Megalopolis: The urbanized northeastern seaboard of the United States*. Cambridge, MA: MIT Press.

Horovitz, B. 2012. After Gen X, Millennials, what should next generation be? *USA Today*, May 3. Accessed February 5, 2020. http://usatoday30.usatoday.com/money/advertising/story/2012-05-03/na ming-the-next-generation/54737518/1.

Huddleston, T. 2016. Legal marijuana sales could hit $6.7 billion in 2016. *Fortune*, February 1. Accessed January 10, 2020. http://fortune.com/2016/02/01/marijuana-sales-legal/.

Kang, S., J. O'Leary, J. Miller. 2016. From forbidden fruit to the goose that lays golden eggs. *SAGE Open*, 1-12.

Kendall, W. D., & Colorado. Demographic Section. 2002. *A brief economic history of Colorado*. Denver, CO: Center for Business and Economic Forecasting, Inc.

Noel, J. 2010. Colorado: The Napa Valley of beer. *Seattle Times.* Accessed January 10, 2020. https://www.seattletimes.com/life/travel/colorado-the-napa-valley-of-beer/.

Regional Plan Association. 2014. America 2050: Megaregions. Accessed December 22, 2020. http://www.america2050.org/content/megaregions.html.

Svaldi, A. 2019. Millennials still have a crush on Denver, survey finds. *Denver Post*, March 27. Accessed January 14, 2020. https://www.denverpost.com/2019/03/27/millennials-denver-meyers-survey/.

Denver Post. 2018. California has Silicon Valley. Could Colorado become home to "Aerospace Alley?" *Denver Post*, November 25. Accessed February 10, 2020. https://www.denverpost.com/2018/11/25/colorado-aerospace-alley-economy/.

Todorovich, P. 2009. America's emerging megaregions and implications for a national growth strategy. *International Journal of Public Sector Management* 22 (3): 221-234. doi:10.1108/09513550910949208.

Todd, A., D. McKnight, and L. Wyatt. 2003. Abandoned mines, mountain sports, and climate variability: Implications for the Colorado tourism economy. *Eos, Transactions American Geophysical Union* 84 (38): 377-386. doi:10. 1029/2003EO380002.

U.S. News. 2019. Best States: Colorado. *U.S. News & World Report*. Accessed January 9, 2020. https://www.usnews.com/news/best-states/colorado.

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SANGRE DE CRISTO MOUNTAINS: BLANCA AND TRINCHERA RANCHES

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Figure 1. Culebra Range in the Sangre de Cristo Mountains (Hoyt 1999).

Starting in south central Colorado and extending into northern New Mexico are the rugged, picturesque Sangre de Cristo Mountains, also known as the "Sangres." These mountains form the southernmost range of the Rocky Mountains. They start from Poncha Pass at the north end of the San Luis Valley in Colorado and continue to Glorieta Pass near Santa Fe, New Mexico, a distance of 366 km (231 miles). Their greatest east-west dimension is 80 km (50 miles) wide and in area they cover an estimated 44,530 km^2 (17,193 sq. miles). They are narrow in form and well defined from surrounding areas. Figure 2, a NASA MODIS (Moderate Resolution Imaging Spectroradiometer) image offers an overhead view of the mountain chain. The image clearly shows the bright snow-capped peaks in sharp contrast to the darker greens and browns of the surrounding landscapes. Within a short distance the mountains rise, on the average, 1,850 m (6,069 feet) above the adjacent valleys and plains that are already at elevations between 1,500 and 2,300 m (4,921 and 7,546 feet) above sea level. Their east facing slopes have economic farming ties to the Great Plains, and their western slopes have strong, cultural traditions associated with the Hispanic and Native American settlements of the San Luis Valley and along the Rio Grande. Just the name "Sangre de Cristo" reflects the Hispanic heritage of the western slopes. From Spanish it translates as the "Blood of Christ."

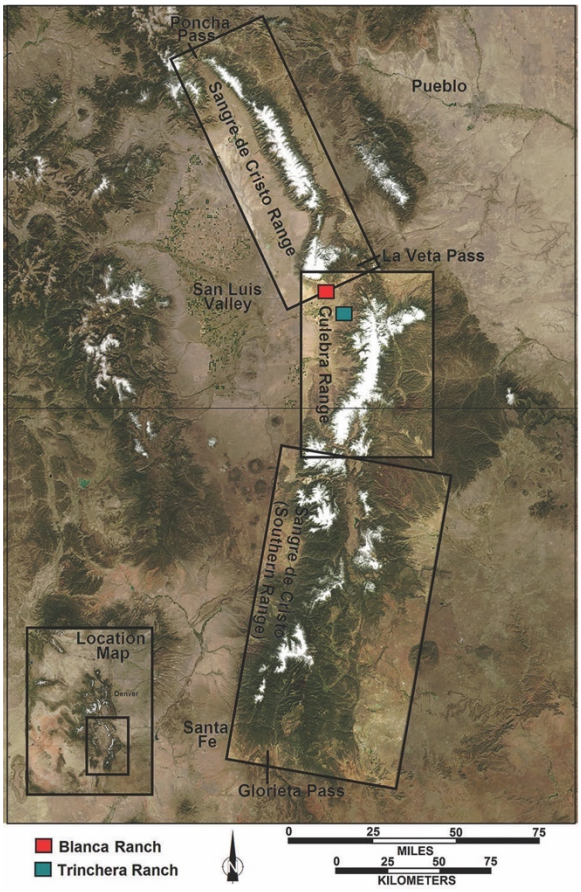

Figure 2. MODES satellite image, 20 September 2002 (Descloitres 2002; annotated by author 2019).

This mountain chain can be divided into three ranges, highlighted on Figure 2. The northernmost section is the Sangre de Cristo Range. (This name should not be confused with the name, Sangre de Cristo Mountains, that is used to refer to the entire mountain chain.) This is basically a young, fault block range situated between two north-south fault lines. The peaks are rough and dramatic in appearance. On its west side is dryland farming associated with the northern San Luis Valley and on the east side it forms part of the Arkansas River watershed. The middle section is the Culebra Range, sometimes referred to as the Snowy Mountains as illustrated in Figure 1. It is also a long, fault block uplift. It provides irrigation water to the ranches and farms on its west side and on its east side it extends into an old, volcanic field dominated by the East and West Spanish Peaks. The third section consists of several subranges and does not have one single name. Collectively, these subranges are occasionally identified as the Southern Sangre de Cristo Range. Located mainly in northern New Mexico they furnish scenic backdrops for the art/tourism economy found in places like Santa Fe and Taos. This economy centers on the Hispanic and Pueblo traditions of the region. The mountains on the east side supply the headwaters of the Pecos River, an area sparsely populated and rooted in a ranching economy (Wolf 1995).

Sangre de Cristo Grant

After Mexico obtained independence from Spain in 1821, it established 197 land grants in what is today northern New Mexico and southern Colorado. The principal purpose of these grants was to curtail the expansion-minded Americans from entering Mexico via the Santa Fe Trail. Although most of the grants were small, a few were quite large. One large grant was the Sangre de Cristo Grant. This grant was established in 1841 and covered 404,686 ha (1 million acres) and commenced from the ridgeline of the Culebra Range and extended westward down into the San Luis Valley to the Rio Grande. Figure 3 shows the grant's boundary line as it relates to the present-day landscape. After the Mexican-American War, when the area became better protected against Ute raids, Hispanic settlers from Northern New Mexico immigrated to the grant and settled in small plaza centered villages, the largest one being San Luis (Figure 3). In the 1860s, nearly half (202,343 ha; 500,000 acres) of the grant was sold to William Gilpin, Colorado's first territorial governor. He purchased the mountain portion of the grant. In 1868 Gilpin and his partners divided the property into two large ranches, the Trinchera Estate (northern section) and the Costilla Estate (southern section). The Costilla Estate was also called La Sierra and later known as the Taylor Ranch and the Cielo Vista Ranch. Both estates were about 101,171 ha (250,000 acres). Over the next seven decades the Trinchera section had several owners and except for some small parcels totaling 2,833 ha (7,000 acres) that were sold, no major changes in size occurred with the ranch. In 1939 Ruth Hanna McCormick Simms acquired the ranch and in 1950 her family divided the property into two ranches. The southern portion (60,703 ha; 150,000 acres) of the ranch was kept by the family and it maintained the name "Trinchera." The northern portion (36,422 ha; 90,000 acres) was named "Blanca" and was sold (Draper 2001).

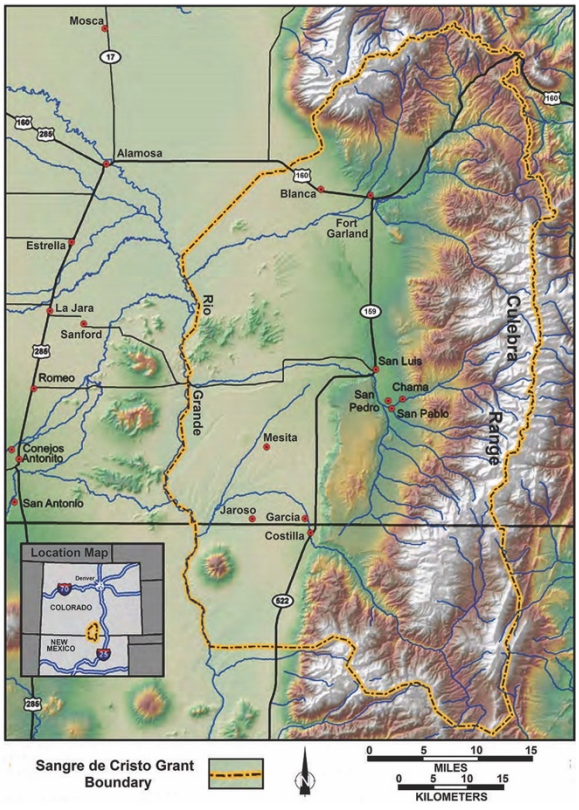

Figure 3. Boundary and location of the Sangre de Cristo grant. (U.S. Fish and Wildlife Service 2012).

Trinchera: Malcolm Forbes

In 1969, Trinchera was sold to Malcolm Forbes, the publisher of *Forbes* magazine. He paid $3 million for the ranch that covered 60,702 ha (150,000 acres) (Armstrong, 1978). Forbes was a capitalist and free market trader; he was not an environmentalist or rancher. Initially he wanted to have the ranch as a private hunting preserve and was going to fence in the entire ranch to keep the wildlife from escaping. The State of Colorado stopped this endeavor indicating that the wild animals did not belong to Forbes and he could not contain them. Next he tried cattle ranching by mainly leasing high meadow land as summer pasture to smaller ranchers. The ranch also supplemented its income by harvesting trees for lumber and providing big game hunting, especially for elk.

In 1971, just two years after acquiring Trinchera, Forbes divided a large section of the ranch into 2 to 8 ha (5 to 20 acres) rural residential lots and created an unincorporated subdivision named the Sangre de Cristo Ranches. It had 8,000 lots, mainly situated in the piñon pine and juniper portions of the ranch, at elevations ranging from 2400 to 2600 m (7874 to 8530 feet). Lot sales were completed in 2000. Next, in the mid 1970s, he created a second subdivision and named it, Forbes Park. This subdivision is forested with aspen, spruce and fir trees interlaced with alpine meadows and ponds. The Park's elevation varies from 2,560 to 3,140 m (8,400 to 10,300 feet). Although developed by Forbes it is now maintained by a landowners association as a gated community. In the early 1980s a third subdivision, named Forbes Wagon Creek Ranch, was established, again removing land from Trinchera. Like Forbes Park it is located in an alpine environment both with respect to vegetation and elevation. It is also a gated community with a landowners association. This subdivision as well as the second subdivision has "Forbes" in its name. This attracted a number of investors, (domestic and foreign) to acquire lots in these subdivisions expecting the lots to increase in monetary value because of the Forbes' name.

Table 1 summarizes the amount of Trinchera land consumed by these three subdivisions. With 11,604 subdivision lots and 35,070 ha (86,600 acres) of land almost 58% of the original ranch was fragmented into rural residential lots. Access roads were needed to reach these lots. In Forbes Park alone 182 km (113 miles) of dirt roads were bulldozed out of the alpine environment.[1] Figure 4 illustrates spatially the fragmentation of the Trinchera Ranch. Forbes discovered that the profit level was much better in selling real estate than farming the ranch. Based on how quickly he moved to establish the first subdivision after purchasing Trinchera it is apparent that he was viewing the ranch more as a real estate venture rather than a farming endeavor.

Trinchera is located in Costilla County, one of the poorest and most sparsely populated counties in Colorado. The county government is the main source of employment. Part of the ranch's economic structure relates to its low agricultural tax base. By selling portions of its land it reduced the amount of property taxes it was paying. However, the owners of the subdivision lots have to pay higher property taxes due to the land being reclassified as residential in nature. For a poor county like Costilla this additional tax revenue helps in providing financial support for its people, but at the same time it faces the issue of how much support it gives to the fragmentation of the mountains (Wolf 1995).

In 1982 Forbes purchased the 36,421 ha (90,000 acres) Blanca ranch, which is across U.S. 160 from the Trinchera (Figure 4). The two ranches were renamed the Forbes Trinchera Ranch. Again, Forbes stated he wanted to create a hunting preserve but as with Trinchera the State of Colorado stopped him. Forbes brought out his bulldozers to carve out roads for a new subdivision on Blanca. These roads are still visible on the slopes of Mt. Blanca. In order to keep more land from being fragmented Colorado and Forbes came to an agreement on the issue of hunting.

In 1990 Forbes died and his family inherited the Forbes Trinchera Ranch. In 2004 the family placed the Trinchera portion of the ranch in a conservation easement by donating it to the Colorado Open Lands, a 501(c)3 nonprofit land trust.[2] This was

[1] Google Earth's path tool function was used to ascertain mileage. In total area Forbes Park is the smallest of the three subdivisions but it has the greatest density of roads.

[2] A conservation easement provides perpetual protection of natural habitats and wildlife corridors on private lands, and thereby, eliminates the fragmentation of private land through

Table 1. Trinchera subdivisions.

	Time Established	Area	Number of Lots	Lot Size	Percent of Total Ranch Land
Sangre de Cristo Ranches	1971	22,727 ha. (56,160 ac.)	8000	2.0 to 8.0 ha. (5 to 20 ac.)	37.44%
Forbes Park	Mid 1970s	5,463 ha. (13,500 ac.)	3200	0.40 to 2.8 ha. (1 to 7 ac.).	9.00%
Forbes Wagon Creek Ranch	Early 1980s	6,880 ha. (17,000 ac.)	404	16.2 to 28.3 ha. (40 to 70 ac.)	11.53%

done for income tax reasons. In 2005, the family created the company, Forbes Trinchera Ranch LLC, as a means to maintain its conservation easement tax status and at the same time develop another subdivision. The company would lease 2,023 ha (5,000 acre) lots. The easement allowed hunting and under this arrangement individuals could lease a lot and build hunting lodges. The family would keep ownership of the land with its tax status and would make an estimated $70 million (Bloomberg News 2005). This subdivision did not materialize mainly because in 2007 the family sold the Forbes Trinchera Ranch.

Trinchera-Blanca: Louis Moore Bacon

In 2007, Louis Moore Bacon, founder of Moore Capital Management, purchased the 69,606 ha (172,000 acres) ranch for $175 million. Bacon is a self-made billionaire and a conservation philanthropist with over two decades supporting environmental endeavors throughout the world. In 2012 he donated the Blanca section of ranch as a conservation easement to the U.S. Fish and Wildlife Service (Mac, 2012). The Trinchera section was already in a conservation easement. With this donation the entire western slope and high peaks of the Sangre de Cristo Mountains fell under some type of environmental protection. The only exceptions are the three subdivisions developed by Forbes and some small ranches. North of Blanca are the San Isabel National Forest, the Great Sand Dunes National Park and Preserve, and the Nature Conservancy's Zapata Ranch. South of Blanca are the Trinchera section of the ranch, the Taylor Ranch

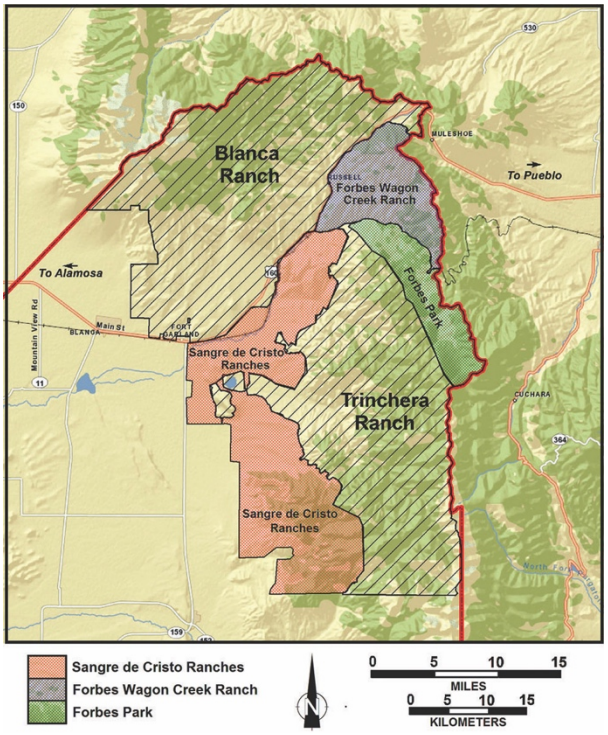

Figure 4. Trichera Ranch's subdivisions (U.S. Fish and Wildlife Service 2012; modified by author 2019).

that is also under a conservation easement, the 226,624 ha (560,000 acre) Ted Turner Vermejo Park Ranch (Turner is a noted philanthropist and environmentalist), and three national forests. A protected natural corridor of 2,023,428 ha (5,000,000 acres) now exists the entire length of the Sangre de Cristo Mountains, allowing wildlife to move freely. The only breaks in this corridor are

subdivisions. A private landowner donates his/her land to a qualified conservation organization or a local, state, or federal government agency. The landowner continues to use the land within the confines of the easement contract. The easement is linked to the property's deed and continues to exist with the property when it is sold or transferred to another person.

U.S. 160 over La Veta Pass and U.S. 64 through the mountains east of Taos.

In addition to the corridor, Bacon has been working at improving the forest health on the ranch. Crowded forest stands, spruce budworms, two recent wildfires, and a 20-year Southwest drought have killed large sections of the evergreen forest over the ranches and surrounding lands. To handle these conditions and create a healthier forest Bacon is removing and processing the dead trees (Hildner 2016). Although logging and thinning of the forests on the ranch had been routinely done in the past, Bacon, in 2016, took the process one step further and built a sawmill that is designed to function as a sustainable timbering operation. Among other things it can handle trees as small as 14 cm (5.5 inches) in diameter (the norm being 30.5 cm; 12 inches) and generate its own power using shredded bits of wood scraps in a boiler. The mill hires between 40 and 60 people making it the largest employer in a poor county. It shows that an area historically associated with a resource extraction economy can have a manufacturing economy based on its resources (Blevins 2019).

He is also addressing issues related to past grazing and lumbering practices on the ranch. Sagebrush is being removed in certain meadows to allow native grasses to return. Conifers are being taken out in riparian areas in order to have more space for cottonwoods and aspens to grow, trees that are native to wetlands adjacent to streams. Dense undergrowth and conifers are being eradicated on some mountain slopes to allow ponderosa pine savanna ecosystems to come back. Actions of this nature are attracting scientists, federal land managers, and other landowners seeking knowledge of how to create healthier forests and to protect wildlife alongside hunting, grazing, logging and other resource development (Blevins 2019). The Colorado Division of Wildlife is using the ranch as an outdoor laboratory (Weber 2018).

Bacon's conservation easement donation inspired U.S. Interior Secretary Ken Salazar to establish in 2012 the Sangre de Cristo Conservation Area as a unit of the National Wildlife Refuge System (U.S. Fish and Wildlife Service 2012). Salazar is a resident of the San Luis Valley, former U.S. Senator, and Interior Secretary in the Obama administration. This conservation area covers the original Sangre de Cristo Grant as outlined in Figure 3. Costilla County, Colorado makes up 79% of the grant's former territory with the remaining 21% in New Mexico. Turner's huge Vermejo Park Ranch forms most of the New Mexico portion of the grant.

With the mountainous eastern half of the grant area now secured from future fragmentation of land for second/vacation home development, attention has now shifted to the western half of the grant area. This half is relatively flat and covered mainly with sagebrush with very few trees. Some center pivot irrigation fields exist here. In the early 1970s, when Forbes started his first subdivision, several large subdivisions were established in the western half of the grant, the two largest being the San Luis Valley Ranches and the Rio Grande Ranches. These subdivisions stretched out over nearly half of the flat valley floor with their rectangular arranged dirt roads. They had nice views of the mountains but they were not in the mountains as the real estate brochures suggested. The Federal Trade Commission charged Bankers Life and Casualty Company of Chicago and 11 other companies who owned these subdivisions with misleading buyers and described the land as being "worthless, either as an investment or for homesites" (King 1979). The sellers were forced to compensate financially the buyers. Most of this land now sits dormant and is available to be incorporated into the Sangre de Cristo Conservation Area.

Conclusion

A number of large ranches still remain in the Rocky Mountains and on the High Plains. The owners of these large land tracts need to be brought together to explore ways that they can maintain their holdings without fragmenting them into second/vacation home subdivisions. Some of these owners are already looking for ways to protect their ranches and most likely would enjoy exchanging ideas on how they might maintain their land. These individuals might form an alliance to help each other and rather than come together only once have regular meetings. Such meetings might become think tanks and include people from organizations such as Nature Conservancy, National Wildlife Federation, and Sierra Club. Two items that this alliance might address are the development of a standard conservation easement agreement document and the establishment of one donation holder for large ranches. At the present time conservation easement documents have various agreement con-

ditions and loopholes exist as illustrated by the Forbes family trying to subdivide the remainder of the Trinchera Ranch into lease arrangements. A donation holder can be a qualified conservation organization or a local, state, or federal government agency. By having one donation holder for all of the ranches under a conservation easement the alliance can become a strong political force in protecting the environment. Having a standard holder would eliminate local and state agencies. A federal agency would have the resources to monitor easements on a regular basis and nationally based conservation organizations such as those previously mentioned have the motivation to make sure landowners remain true to the easement agreements. Having more than one easement holder can lead to piecemeal arrangements. Bacon has to deal with Colorado Open Lands pertaining to the Trinchera portion of the ranch, a situation established by the Forbes family, and the U.S. Fish and Wildlife Service with respect to the Blanca section of the ranch. It would be functionally better to have the entire ranch under one donation holder. Keeping these large ranches intact is not only important to the environmental movement but is part of the popular movement to reclaim the spirit of the West (Flores 2002).

References

Armstrong, R. 1978. *Promised land, a history of the Sangre de Cristo Land Grant.* New York City, NY: Forbes Inc.

Blevins, J. 2019. This Colorado ranch-made-lab is turning beetle-kill trees into lumber in the name of forest health. *Colorado Sun* June 11. Accessed November 22, 2019. https://coloradosun.com/2019/07/11/trinchera-blanca-ranch-forest-health-lab/.

Bloomberg News. 2005. Forbes heirs to preserve half of Colo. ranch for tax breaks. *Denver Post.* November 9. Accessed November 15, 2019**.** https://www.denverpost.com/2005/11/09/forbes-heirs-to-preserve-half-of-colo-ranch-for-tax-breaks/.

Descloitres, J. 2002. First snow in Colorado. NASA Goddard Space Flight Center, MODIS Land Rapid Response Team at September 20. Accessed October 10, 2019. https://www.visibleearth.nasa.gov/images/99462/first-snow-in-colorado.

Draper, E. 2001. Ranch roots stretch back to days of million-acre grants of 1800s. *Denver Post Four Corners Bureau*. January 28. Accessed November 27, 2019. https://extras.denverpost.com/news/forbesside0128.htm.

Flores, D. 2002. *The natural West: Environmental history in the Great Plains and Rocky Mountains.* Norman, OK: University of Oklahoma Press.

Hildner, M. 2016. Big ranch. Big problem. Big plan.: Cutting timber on a billionaire's land could improve forest health *and* boost the local economy. *Pueblo Chieftain.* May 28. https://medium.com/small-towns-big-change/can-a-ranch-sawmill-improve-forest-health-c7539a279686.

Hoyt, A. 1999. Free Sangre De Cristo Mountain Range Stock Photo. FREEIMAGES. Accessed November 20, 2019 https://www.freeimages.com/photo/sangre-de-cristo-mountain-range-1374115.

King, S. 1979. Buyers to get refunds on worthless land in Colorado. *New York Times.* May 10. Accessed December 3, 2019. https://www.nytimes.com/1979/05/10/archives/buyers-to-get-refunds-on-worthless-land-in-colorado-visions-of.html.

Mac, R. 2012. Hedge fund billionaire Louis Bacon to donate 90,000 acres for Colorado Conservation Area. *Forbes.* June 12. Accessed November 1, 2019 https://www.forbes.com/sites/ryanmac/2012/06/15/hedge-fund-billionaire-louis-bacon-to-donate-90000-acres-for-colorado-conservation-area/ #5b3fd1fc25d5.

U.S. Fish and Wildlife Service. 2012. *Land protection plan, Sangre de Cristo Conservation Area, Colorado and New Mexico.* Lakewood, CO: U.S. Department of the Interior, U.S. Fish and Wildlife Service. Accessed November 1, 2019. https://www.fws.gov/mountain-prairie/refuges/lpp_PDFs/ sdc_lpp_all.pdf.

Weber, N. 2018. Spring Creek fire burns former Forbes Ranch, Colorado's largest private land holding home to three 14ers: Trinchera Ranch is used as an outdoor wildlife laboratory, conservation easement. *Denver Post.* July 9. Accessed November 10, 2019. https://www.denverpost.com/2018/07/09/spring-creek-fire-forbes-ranch-colorado-private-land/.

Wolf, T. 1996. *Colorado's Sangre de Cristo Mountains.* Niwot, CO: University Press of Colorado.

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A LITTLE PLACE IN THE COUNTRY

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Introduction

Notoriously footloose, Americans are engaged in yet another residential redistribution variously dubbed the Rural Renaissance, Rural Rebound, and more recently Rural Sprawl. By the end of the 1970s demographers reported many non-metropolitan counties experiencing greater population growth than metropolitan, something that had not happened in 150 years. Citizens opted to move away from big cities causing some people watchers to naively pronounce a Rural Renaissance afoot. Mid-1980's national economic woes, however, prompted a return to long-standing rural-to-urban migration. By the 1990s dominant movement had reversed again and numerous non-metropolitan counties outgrew nearby metropolitan areas, a trend dubbed Rural Rebound.

Most U.S. counties—53%—lost population from 2010-2014; geographic situation is key to pattern of gain or loss. Counties closer to metropolitan areas grow, often rapidly, while most remote counties remain in decline. Regionally, census-defined western states have the most rural growth counties, two of every three. In varying degrees and places ruralward movement continues, encroaching upon established agricultural land use and landscapes, notably in Colorado. Unfortunately, little rural cultural revival is evident as most rural newcomers are two generations removed from any agricultural heritage and find themselves still bound to city jobs and city life. Competition and conflict over land and water use, space, environment, and rural practices and customs mark this newest chapter in national restlessness, earning the label Rural Sprawl.

Purpose

No comprehensive examination of rural sprawl is intended. While I am of the mind low density rural residential land use is expensive and fraught with problems wherever it occurs, my specific purpose is to present a one-county case study of rural sprawl promoted by a specific innovation in modern farming—the Center Pivot Sprinkler (CP) irrigation system, and abetted by distance nullifying innovations of satellite-linked PCs, modems, uplinks, Internet, and cell phones.

Study Area

Weld County encompasses 4,000 square miles in northeastern Colorado. By virtue of size and access to water, it boasts the highest agricultural production east of the Rocky Mountains; nationally, Weld ranks between fifth and tenth most productive farming and ranching county. Cattle constitute the most valuable commodity but much of the county is devoted to growing feed to produce beef, lamb, poultry, and dairy products.

Mid-summer in irrigated Weld is reminiscent of Iowa or Illinois with verdant landscapes made possible by regular "rainfall" from an ever-growing flock of Center Pivot (CP) sprinklers (Figure 1). In addition to local water resources, 400,000 acre feet of water are imported annually from the distant Colorado River system, the lion's share to Weld. Increasingly, CP systems apply this critical resource to local fields.

Figure 1. A typical and basic Center Pivot Sprinkler. Photo by author.

Center Pivot Sprinklers

Like shiny plodding dinosaurs, a burgeoning herd of CP systems dominate the landscape of Weld County. Fittingly, local farmer Frank Zybach designed the first practical automated artificial rain system for sub-arid fields of northeastern Colorado (Othmer 2016). As the name suggests, water is

pumped to a center point—the pivot—of the field or area being irrigated. Rotating about this pivot on sets of motorized wheels, a horizontal pipe carries water discharged from regularly spaced nozzles. Computer controlled, ideally the system rotates endlessly applying a uniform measured amount of water, literally at the touch of a button.

CP systems are a classic substitution of capital for labor, and despite costly equipment, installation, maintenance, and energy, their water efficiency and labor savings make CPs popular. Typically, CPs replace traditional flood furrow irrigation in which water is flooded across a field's surface via multiple small closely spaced open ditches. Flood furrow has low capital and operation costs but is very labor intensive. Critically, it uses water inefficiently owing to high evaporation, run-off, seepage, and over-watering.

But there is a problem. CP-created round fields waste land. Figure 2 represents a 160 acre field—one quarter of the mile-square sections so common in the western U.S. Note almost 20% of the area in the field's corners, the stippled zones, is not watered by the basic system.

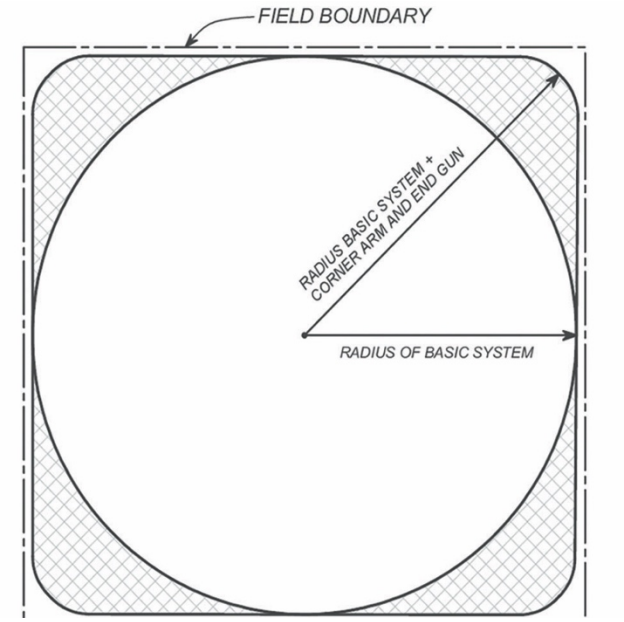

Figure 2. Coverage of a single Center Pivot Sprinkler on a 160 acre field (Design and Operation of Farm Irrigation Systems. ASABE).

It is 21st century reality that technology begets more technology, that a problem created by automation be resolved by more technology. If the CP is equipped with an end gun more ground is covered. But additional equipment adds to initial cost plus operational expense for the added technology. Note also the term "corner arm." Some CP companies call it "squaring the circle," a programmable extension to the system that alternately folds out into corners and retracts. New cost of a basic CP irrigating 125-130 acres of a 160 acre field is about $70,000, apparatus cost only. If a corner arm is added apparatus price increases by $45,000 and operating cost rises, too—at minimum more electricity to power a bigger water pump and move added sprinkler towers. A 60% increase in capital cost to add a 15% increase in acreage is not a formula for success.

CP adapters face a dilemma. Unirrigated land in Weld County raises little save small grains (wheat, barley), drought-tolerant grasses, weeds, and prairie dogs. Unirrigated field corners may use the traditional flood furrow, but not usually or efficiently. Creating a separate irrigation system for corners, each about eight acres, is often impractical. Parcels are too small to reasonably amortize initial costs. Presented with this reality farmers may leave corners unplanted or seeded to a cover crop, e.g., grass. Even this means periodic tilling or mowing—an expense with no revenue. Farmers may build CP ponds on corners, use them to store feed and equipment, but with no actual revenue. Some few relinquish corners to spontaneous weed nurseries and rural junkyards. But increasingly there is the ranchette option.

At issue is best use of "niche landscapes" created as CP irrigation expands across the historically rectangular farmscapes prevalent in the western states and specifically Colorado. This "round peg in a square hole" presents obstacles and opportunities for farmers as well as folks aspiring to A Little Place in the Country, a Personal Ponderosa, what I choose to call "Ranchetters" (Figure 3).

The Niche

It is not particularly easy to take up a ranchette lifestyle in Weld County. First is the challenge of buying land zoned agricultural. In many parts of rural America one cannot simply go into the countryside and summarily buy a little piece of farm or ranchland for a home site. Agricultural land use zoning exists and is as pertinent as urban and suburban planning in their realms.

In 1972, legislators approved a 35 acre minimum parcel size for agricultural zoned land. As Colorado's agriculture powerhouse, Weld County set its

Figure 3. Three relatively new ranchettes occupy two adjacent Center Pivot corners. Photo by author.

minimum instead at 80 acres of irrigated land to forestall fragmentation of agricultural areas by proliferation of scattered residential parcels. This more stringent requirement is ostensibly to "protect agriculture" and assure its continued prominence. But all systems have limitations, loopholes and accommodations.

Recorded Exemptions

The Weld County Department of Planning Services monitors and administers rural land use statutes. Landowners can apply for a Recorded Exemption to create 2, 3, or 4 sub-minimum parcels, or those desiring such a parcel can initiate the process, one requiring multiple forms and documents as well as significant application and platting fees. It is not a simple, quick, or inexpensive process and not all applications are approved.

A decade of Recorded Exemption applications (1990-2000) reveals an evolution. Not all were for CP corners but all could be classified as ranchetters, folks seeking a rural building site. In the early 1990s CP corners were sold almost as an afterthought. Reasons given were varied and at times poignant: "To pay for my wife's cancer treatments" wrote one farmer; another said "after last year's hail I need operating funds for this year." A third, wanting to show he was not trying to sell good farmland explained "that corner often floods, it would be a good place for a house."

As CPs multiplied farmers became more aware of market value of corner fragments. Approaching 2000 it was common to read "we are buying a CP, selling a corner will help pay for it." Selling CP corners became part of the process to modernize farm operations. The sprouting of new houses on CP corner lots was not lost upon farmers, and certainly not upon local realtors.

Fast forward to 2019: A developer—not a farmer—offers a CP corner containing three building sites each priced $135,000 (Figure 4). Required Recorded Exemptions are signed and sealed and part of the package thanks to the developer. The house in the background is also a ranchette on a CP corner. From 1973 through 2017, more than 5,000 exemptions were approved producing over 9,600 sub-minimum lots in Weld's agricultural zone. Not all are home sites but clearly those are the majority.

Figure 4. A developer offers three building sites on one CP corner. Photo by author.

On the same farm half mile away from Figure 4 another corner ranchette displays a reality of this rural lifestyle. Virtually no one makes a living on corner parcels; this is a commuting life choice (Figure 5). Left behind is a house in the city but not city-based employment and income. Dogs and horses roam a large backyard but a sense of neighborhood and community can be hard to achieve. Adjustments to rural living are many.

Figure 5. A ranchetter's lament. Photo by author.

Push and Pull

Virtually every decision to change place of residence involves push and pull factors and forces. Reams of research measure the relative importance of push versus pull; however, conventional wisdom emphasizes the role of urban America in pushing people—to suburbia, to exurbia, and for some to rural America.

Consider, instead, a rural pull factor. Money, or a sense of bargain, is a great initiator. A two-income

family with children aspires to a larger home and more room. Jobs dictate an urban location or commuting. Hurdle one is likely real estate cost. A bare-ground city subdivision lot (one-fifth acre) costs about $70,000 in Weld County while a three- to four-acre CP corner is available for $135,000. Simple math can conclude rural space is more affordable. Less evident are construction costs, water, electricity, heating options, waste disposal, private roads, fencing, vehicle wear and tear, and accessing goods and services, e.g., groceries, medical/dental, most shopping. These can make rural living more expensive than suburbia. However, a cost-benefit analysis of family perceived values of privacy and space, room for animals, scenic surroundings, wildlife, less traffic, less crime, less school crowding—for some these surpass out-of-pocket costs. This hypothetical family is not alone. Community preference polls indicate respondents desiring a small town or rural lifestyle exceed the population currently living in these situations. In Weld one can dispense with hypothetical choices and preference polls. People are exercising an urge to relocate to rural sites even when this choice can mean fewer services, more expense, and coping with unanticipated aspects of rural culture. Yet new dwellings blossom like spring crops.

A Personal Ponderosa

The niche landscape of the ranchette (Figure 6) is replete with a set of shared earmarks. An elaborate ranch gate is *de rigueur,* with or without connecting fence or livestock: gate size-to-acres owned is an inverse relationship. Homes range from McMansion to suburban ranch to modular. Steel sheds are mandatory sheltering two or more vehicles, one often a large SUV or 4WD pickup, a horse or stock trailer, a small tractor or large riding mower to maintain the acreage and plow snow.

Horses, horse sheds, horse trailers, and haystacks abound. Satellite dishes are obligatory, and one or more dogs seem nearly so. Livestock variation is truly amazing—goats, sheep, alpacas, emus, llamas, burros, horses, chickens, turkeys, guinea fowl, pea fowl, and even bovines roam the Personal Ponderosa.

Curiously, one sees little reference to "farmettes." Farmers and farming do not enjoy the *cachet* of ranching, attributable I feel to the abiding popularity of horses, riding, and an enduring fascination with things "cowboy." Regardless of background or experience, ranchetter reality is that new neighbors will likely be farmers, not ranchers. Challenging adjustments await.

Figure 6. The ranch gate is out of proportion to the "ranch" but bespeaks an idealized notion of country living. Photo by author.

The Right to Farm and the Code of the West

Visitors to Weld County unacquainted with agriculture puzzle at signs along county boundaries (Figure 7). The minimalist message fails to reveal land use conflict in rural Colorado involving two very different notions of both agriculture and countryside. The crux of the matter—discussed below—is that some rural newcomers, unprepared for the sounds, smells, and sights of industrial agriculture, file lawsuits to stop traditional farming or ranching practices.

First, we do not assume those desiring a ranchette lifestyle are all refugees fleeing asserted ills of inner-city America or the cultural wasteland of suburbia, or in Colorado, disgruntled Californians. Nor should we hold them all as ignorant about rural living. Owing to its expanding economy Weld draws people from many

Figure 7. Legislation protects Weld farmers from nuisance lawsuits. Photo by author.

origins, most relocating from within Colorado.

What we can posit is few citizens possess accurate knowledge of 21st century agriculture. Given its productivity, farming in Weld is intensive, technological, profit-driven, and what some call industrial agriculture. That means large scale and fast paced. Old McDonald does not farm in Weld (though some ranchetters may aspire to resurrect him). Old McDonald is dead!

And whence cometh the popularized perspective on country living? Titles include *Country, Country Living, Country Woman, Farm and Ranch Living,* a stable of periodicals colorfully extolling the virtues of living away from the city. Published by Trusted Media Brands, Inc.—formerly Reader's Digest Association most began in the 1980s to early 2000s, coincident with the Rural Renaissance and Rural Rebound. Meanwhile, a google search of "Country Living" produces 41.4 million items. Themes shared by these mass media focus on simplicity, space, tranquility, environment quality, beauty, healthfulness.

As the 20th century closed, John Clarke served as Larimer County Commissioner (Larimer is adjacent to Weld) and authored the *Code of the West,*[2] a reality checklist for those contemplating rural living. Adopted by 150 jurisdictions (though not Weld) the *Code's* values and advice exist in Weld County's *Right to Farm* statement (Larimer County Planning Department n.d.). Among the most pertinent areas of advice:

- Environment: rural life often is not pristine. Dust, smoke, odors, noise, and other human-caused conditions are inherent in modern agriculture.
- Transportation: Traffic volumes are less than in cities but different in nature and content.
- Peace and Quiet: Tractors, harvesters, trucks, aerial (airplane) crop spraying, feedlots, and dairies are noisy. Some operate around the clock.
- Social Services: Fire, medical, law enforcement response times are longer than for cities or suburbs.
- Utility Services: potable water, sewerage, waste disposal may be solely homeowner responsibility. Utility services typically cost more than in cities.
- Water (For irrigation): Water in lakes, ponds, and canals belongs to those who depend upon it for a living, it is not a public resource.

Ranchette Realities

Note how near are worked field and ranchette (Figure 8). When conditions dictate, tractors, harvesters, and the CP operate a few yards from this residence 24/7, especially irrigation. Should the field require spraying, chemical herbicides and insecticides can drift into the yard, especially with aerial application. Right to Farm statutes mean normal and established practices, e.g., spraying or weed burning or harvesting at midnight cannot be challenged by the ranchetter. However, this has not prevented hard feelings, misunderstandings, protests, and spurious lawsuits.

Figure 8. A curving property line is characteristic of corner parcels. Note how near the field is to the house. Photo by author.

As commuters and haulers of children to school, the orthodontist, and other urban-based needs, ranchette families cope with this altered reality. Large trucks and farm equipment on two lane roads create extended travel times and more hazards (Figure 9). Unavoidably, farm equipment serves as rolling roadblocks, often trailing frustrated commuters. Commuting ranchette parents transition between multilane divided highways, two lane roads and often ultimately unpaved local roads. Fatigue, changing speeds, changing road conditions, diversity of vehicle mix, and impatience contribute to a grim statistic. Federal, state, and county highways carry 78% of Weld traffic, yet from 1994 through 2005, local roads, most unpaved, were the scene of more traffic fatalities than the county's Federal or State highways. Increasingly, home sites at road intersections create more traffic entering or exiting at visually obstructed or "blind" corners. Sadly, multiple rural intersections display spontaneous roadside memorials marking the site of fatal crashes.

Figure 9. Conditions created by large trucks and farm equipment make rural driving stressful and statistically more hazardous than on major highways. Photo by author.

Small size and location mean CP corner ranchettes have minimal setback opportunity. Dust is a constant complaint (Figure 10). With 3,000 miles of road, three-fourths unpaved, maintenance resources are assigned first to highest traffic volume roads. A common ranchette reality is dust, which combines with more dust from field preparation, processing feed and harvest practices. Dust combined with field and ditch burning smoke, and large equipment exhaust means periodically rural air quality is anything but pristine and worse than many urban settings.

Figure 10. On an unpaved county road a ranchette owner appeals to drivers hoping to reduce the dust problem with little success. Photo by author.

Water is a perennial bone of contention in Weld County. Population growth and land fragmentation further exacerbate the situation. Irrigation is absolutely critical to maintaining productive local agriculture and the initial reason irrigation water was imported from the other side of the state. Some ranchetters, probably most, come with an aspiration to have a lawn, keep livestock, or grow some of their own food, essentials of supposed country living. Buying a CP corner rarely includes a water right. Rural water taps or private well drilling is expensive and especially costly if water is used for more than household needs. Yet the ranchette exists amidst a landscape dotted with storage lakes, CP ponds, large canals, and feeder ditches. Issues predictably arise from safety concerns, illegal pumping, and indiscriminate trash dumping.

For large feedlots and mega-dairies, runoff is the issue. By law, wastewater must be held in artificial lagoons. Evaporation from these manure-laced water bodies is one reason for the graffito "Have You Smelled Weld?" Dairies and feedlots also produce mountains of manure which must be stockpiled most of the year. Offensively pungent to some, to others it is the essence of agricultural productivity. Here, too, complaints and potential lawsuits are forestalled by Right to Farm regulations.

Up close and personal, rural reality often digresses from the imagined or desired country living experience. The notion of wide open spaces is a prime example. Predictably, this conundrum has diametrically opposed perspectives. Two years after obtaining his Recorded Exemption, a ranchetter returned to County Planning Services to complain. "Why," he protested, "did you allow me to acquire so much ground?" Upkeep of eight acres consumed too much time. Occasionally, Planning Services is asked to reverse a Recorded Exemption. Size can also be problematic regarding livestock, particularly horses. Owners of a six acre parcel may entertain visions of half a dozen head grazing contentedly, as they appear in *Farm and Ranch Living* magazine, only to discover the little herd quickly reduces grass to bare earth. Yet six acres are not enough for pleasurable riding on the new Ponderosa. County roads, private field roads and ditch bank rights-of-way may seem an ideal option for riding. But farmers often resent trespass riding and are wary of potential lawsuits from riding accidents. These possibilities do not fall under purview of Right to Farm protection.

Rural Sprawl in Weld: Final Thoughts

So, what exactly is the issue? Some say farmland loss. Advocacy group Environment Colorado found from 1997 to 2002, Weld County "lost 271,491 acres of agricultural land," making it the most impacted Colorado county. However, USDA for the same interval documents a 101,436 acre loss. However, the two most recent agriculture censuses (2007-2017) reveal an increase in land farmed! Meanwhile, value of agricultural production is growing, albeit more slowly (Table 1).

Secondly, Recorded Exemptions continue demonstrating a willingness to approve fragmentation (Figure 11). From 1990 to 2017 more than 8,300 were approved, many CP corners. Yet the value of production grows. Whatever the cause-effect relationship, agriculture is doing comparatively well in Weld County despite rural sprawl.

Low density rural residential development does not pay for itself (Davis 2006; Hanson and Brown 2005). Despite greater tax yield on CP corners "growing" homes versus raising crops or cattle, it is inadequate to pay for increased service demands of a spatially dispersed clientele. Four farmed acres generate $125 in property tax while a four-acre CP corner with $350,000 dwelling produces over $3,000. Yet, for each $1.00 of tax revenue, appropriate services cost $1.30-$1.60. Ultimately, public funds must make up the difference for road maintenance, fire and law enforcement, postal delivery, upgraded utilities, or enrollment growth in small rural school districts.

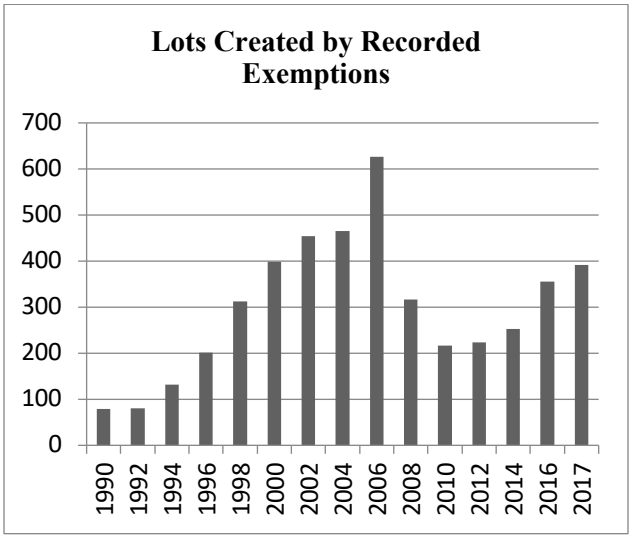

Figure 11. Lots created by Recorded Exemptions. Compiled from Weld County Department of Planning Services files.

Once more we collectively face the dilemma of reconciling individual freedom of choice to pursue a ranchette lifestyle with public interest. Barring a regional economic crash, Weld County ranchette growth is destined to persist. Administrative action to curtail sale of CP corners is unthinkable in conservative Weld County. Plus, there are just too many relative location advantages, namely access to Denver's dynamic metro-region, and another simply called "The View" (Figure 12).

Figure 12. The view from a still undeveloped CP corner parcel. Photo by author.

References

Davis, M. 2006. County Perspectives: A report on 35 acre subdivision exemptions in Colorado. Colorado Counties, Inc., Denver, CO.

Hansen, A. J. and D.G. Brown. 2005. Land-use change in rural America: Rates, drivers, and consequences. *Ecological Applications* 15 (6):1849-1850. doi:10.1890/03-5219.

Larimer County Planning Department. n.d. Code of the West. Accessed February 13, 2020. https://larimer.org/planning/documents/code-west.

Table 1. Agriculture change in Weld County.

Percent Change	2007-2012	2012-2017
Number of Farms	-10	+15
Land in Farms	-6	+7
Average Farm Size	+4	-7
Market Value of Products Sold	+21	+10

Source: United States Department of Agriculture.

Othmer, M. 2016. Frank Zyback: A man who revolutionized agriculture. Iowa-Nebraska Equipment Dealers Association. Accessed February 15, 2020. https://ineda.com/blog/2016/01/15/frank-zyback-a-man-who-revolutionized-agriculture/.

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THE RICH GET RICHER: DEMOGRAPHIC AND LAND-USE CHANGE IN THE RURAL MOUNTAIN WEST

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Introduction

The Mountain West, which includes the states of Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, and Wyoming, is an ecologically, demographically, economically and geographically diverse region. The diverse structure of the Mountain West has been created by the interplay of four important elements: (1) the geographic factors of aridity, topographical ruggedness, natural resource abundance; (2) the related level of geographic isolation; (3) the influence and impact of federal government land-use policy; and (4) the relatively recent incorporation of the region into the global economy.

This diversity is particularly true for the region's non-metropolitan areas, which have less control over their own fates. Non-metropolitan areas in the Mountain West are characterized by a historic, long-term reliance on extractive industries, (mining, ranching, logging) and in selected locations, areas of extensive farming, which are limited due to the general level of aridity across the region and the areas of rugged topography. Additionally, non-metropolitan areas in these states are largely made up of different types of federal lands. Federal lands include national parks, forests, monuments, wilderness areas, military instillations, and American Indian reservations, among others and account for almost one-half of all land (from a low of 29% in Montana to a high of 85% in Nevada). Settlement patterns in the region reflect these basic factors as well as the timing of settlement. Settlement came relatively late to the region, and remains characterized by low density population settlement patterns dominated by large concentrations of population in a few large metropolitan areas. Moreover, rural settlements are often separated by hundreds of miles of desert, mountains, or federally owned lands, which act as isolating elements and constraints on types and rates of population growth (Otterstrom and Shumway 2003).

Non-metro communities in the Mountain West face a number of unique challenges and opportunities due to the interplay of these four driving forces. Many are isolated far from metropolitan areas that could provide supplemental income for residents, and yet the carrying capacity of the local resource base traditionally relied upon (including grazing, irrigated crop agriculture, mining, and forestry) limits their long-term growth potential or even sustainability. These communities are grappling with their isolation and related economic problems or opportunities in several distinct ways. Some have capitalized on distinctive scenic or climatic characteristics to become destinations for lifestyle migrants, absentee "landowners" who gentrify the areas, and retirees and thus become reliant on income generated by tourism, transfer payments, and rural gentrification (Power 1995). Other communities are able to maintain their emphases on extractive industries while simultaneously attempting to diversify local economies to take advantage of the new economies, including those communities that have benefited economically from protected land status in their counties. On the other hand, a number of counties which are isolated, have marginal extractive industries, or do not have high amenity value are increasingly bypassed in terms of economic and population growth/development (Weber 2018).

Current trends in the region are largely the result of economic restructuring. In the early 1980s rural areas in the U.S. have become more tightly integrated into increasingly complex national and global economies (Marsden 1998). Incorporation has led to greater international competition in natural resource commodities, manufactures, and other tradable goods and services. Greater international competition has decreased real prices for natural resources, decreased the importance of primary products to regional and national economies (with resultant employment declines in these industries), and limited the amount and/or spread of rural based manufacturing (Galston and Baehler 1995). These changes have led to the restructuring of rural economies in the U.S., including the Mountain West region, into three types of economic regions: (1) those that have been able to remain competitive in the production of natural resources

(including farming); (2) those that have restructured their economies around local and unique amenities (e.g. national parks); and (3) those that have largely been bypassed (Weber 2018, Jones, et al. 2019). These trends are manifest in patterns of population change, employment change, and land-use/land-cover change.

Arguably the most obvious consequence of the current period of restructuring is the shift of rural areas from being spaces of production to becoming spaces of consumption and the different types of demands that each place on the organization and structure of rural areas (Marsden 1998). The result is a new consumable countryside where production of minerals, cattle, lumber or crops is replaced by an economy based on a new paradigm of the amenity region (Power 1995, Rasker 1996). Increased demands for amenity space, residential and recreational property, second homes, environmental protection and particular cultural traits promote a new and specific vision of what the "ideal" rural area should be like, which can be seen and documented in patterns of land-use/land-cover change.

In summary, the main trends of change impacting the rural west are an increasingly significant economic shift from extractive activities like ranching, mining, and logging to consumer services, retail, business services, and high tech with the concomitant emergence of new uses of rural space, including tourism, recreation, and environmental protection. Weber (2018) groups counties into three main categories: the Booming West, the Protected West, and the Bypassed West. Whatever the categorization attempted, it is difficult to find counties that are perfect examples of each of the categories. We have selected four counties in Utah that we believe are examples of each of these different types of counties: Wasatch County (Booming), Beaver County (Bypassed), Grand and San Juan counties (Protected) (Figure 1). We have selected two protected counties because of the difference in accessibility. While both counties are relatively inaccessible, Grand County is dissected by Interstate 70 and its main attractions (Moab and Arches National Park) are relatively close to the highway. San Juan County is less accessible. All of these counties are heavily influenced by federal/state ownership of large parts of their counties. Wasatch County has the least with 68%, then Beaver with 87%, San Juan with 92% and Grand with 96%. Because of the high ownership of land by the Federal government together with large parts of the federal ownership being administered by the National Parks Service, we are using San Juan and Grand counties as examples of Protected Counties.

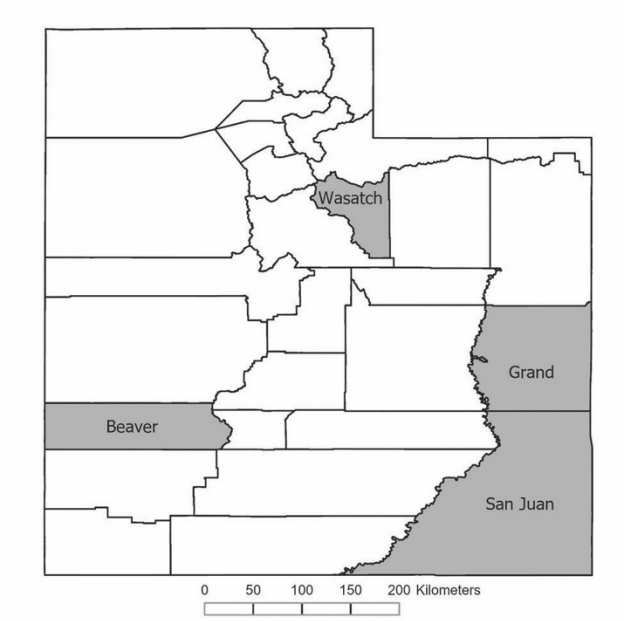

Figure 1. Location of the four counties studied.

Economic and Demographic Change

Previous research on the non-metropolitan west has shown the effects of economic restructuring on the changing distribution of population and types of economic activities across county types (Shumway and Otterstrom 2001; Otterstrom and Shumway 2003; Winkler, et al. 2007; Bryson and Wyckoff 2010; Harner and Benz 2013; Post 2013; Travis, et al. 2005; Keske, et al. 2017; Narducci, et al. 2019). The principal trends are for non-metropolitan counties adjacent to metropolitan areas and counties that have high levels of natural amenities (with relatively higher levels of accessibility) to experience net in-migration and population growth. High amenities counties that are less accessible and lower amenity counties that are non-adjacent to metropolitan areas tend to have low in-migration or net out-migration and low levels of population growth. Here we examine changes in population and economic structure (land-use change is examined in the next section) between these four counties between 1990 and 2015.

Table 1 shows the demographic and employment changes across the four counties and over the 25-year time period. A few patterns stand out. First, Wasatch County is booming with an average annual growth

Table 1. County level demographic and economic status: 1990 and 2015.

	Beaver County (Non-adjacent)		Wasatch County (Adjacent)		Grand County Non-adjacent		San Juan County (Non-adjacent)	
Year	1990	2015	1990	2015	1990	2015	1990	2015
Demographic								
Total Population	4,765	6,414	10,089	29,306	6,620	9,544	12,621	15,193
Percent Non-Hispanic White	95	86	95	82	92	88	42	44
Percent American Indian	0	0	0	0	3	1	54	48
Percent Other	2	3	2	4	1	1	1	3
Percent Hispanic	3	11	3	14	4	10	3	5
Percent Foreign Born	2	5	1	8	1	5	1	1
Employment								
Agriculture, Forestry, Mining	16	26	7	2	7	5	14	6
Construction	5	4	13	9	6	9	6	11
Manufacture	6	8	9	5	4	3	9	4
Transport Utilities	12	9	5	5	8	4	8	4
Wholesale	1	1	2	2	2	6	1	2
Retail	23	12	17	12	28	11	11	8
FIRE	2	2	4	7	5	4	2	3
Professional and Business Services	21	5	24	14	11	6	8	6
Educational Health	14	10	16	18	12	14	24	32
Other Services	10	3	15	4	4	2	6	5
Recreation	1	12	3	18	2	30	3	12
Gov	6	6	3	5	11	6	8	7
Income and Housing								
Median Household Inc (2015 $)	39,019	46,273	51,763	72,053	40,135	46,658	17,289	42,581
Median House Value (2015 $)	91,148	142,363	122,353	345,324	86,740	230,900	40,100	136,600

rate of 7.6% over the past 25 years. On the other hand, Beaver, Grand, and San Juan counties' average annual growth rates are only 1.4%, 1.7%, and 0.84% respectively. Beaver County is a relatively low-level amenity county while both San Juan and Grand counties have high natural amenity values. Additionally, both counties have little land available for expansion and they are relatively isolated. Three of the four counties, with San Juan being the exception, also had what looks like some significant growth in their Hispanic populations. All three counties went from single digit Hispanic populations in 1990 to double digit percentages by 2015. San Juan County also had growth in its Hispanic population, but it was a relatively small increase of two percentage points. San Juan County is also somewhat unique in that one-fourth of the county is made up of the Navajo Indian reservation. This is reflected in its population composition with approximately one-half being American Indian (Navajo and Ute).

A second major pattern is divergent economic shifts among the counties. Two trends are apparent.

First is the loss of employment in retail, professional, health, and educational services due to declines in transportation costs and the emergence of big-box stores in more centrally located towns and cities—the so-called "Walmart effect" (Fishman 2006). A second shift stems from the restructuring of Old West economic activities (agriculture, mining, forestry) to New West activities such as recreation, retirement, and tourism. These trends manifest themselves in all four counties, although with some interesting differences. For example, the decline in agriculture can be seen in booming Wasatch County as well as Protected Grand and San Juan Counties. Beaver County, on the other hand, experienced a large increase due to the location of a large hog farm, which in part located there due to its Bypassed status. Economic restructuring also shifted employment away from retail and business services to health/educational and most conspicuously to employment in the recreation sector, with the largest changes found in Booming Wasatch County and Protected Grand and San Juan counties.

One of the most efficient ways of highlighting the economic and demographic status of counties is examining net migration. Migration is important in terms of both size and composition (who does and who does not move) of its flows. Using the IRS-Census Bureau income migration data between 2011 and 2017, we examine net migration and net income migration into and out of the four counties (Plane 1999). The results can be seen in Figure 2.

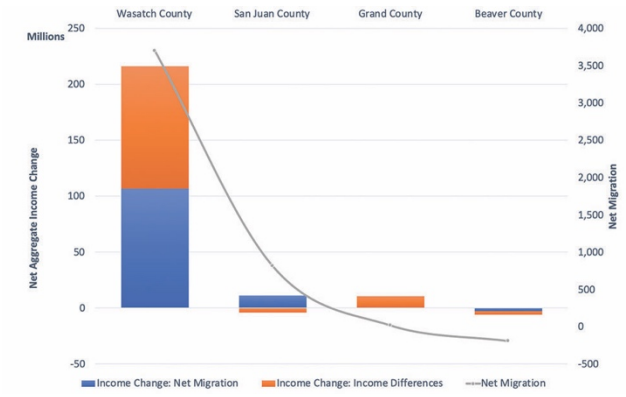

Figure 2. County level net migration and net income migration: 2011-2017.

Between 2011 and 2017 Wasatch County added almost 4,000 new residents with an additional net aggregate income increase of over $216 million. This is typical for non-metro, adjacent, high amenity counties in the Mountain West. On the other side is Bypassed Beaver which experienced net out-migration and a decrease of almost six million dollars in aggregate income. It is important to note here that aggregate income change is due to both the net number of in or out migrants and the differences in income among those different migrant groups. These can reinforce each other or work in opposite directions. For example, in the Protected counties of Grand and San Juan net aggregate income increased by approximately 11 and 8 million dollars respectively. However, almost all of Grand County's income growth came from in-migrants having, on average, higher incomes than out-migrants. San Juan County actually gained 11.5 million dollars from having more in-migrants than out-migrants, but lost about four million dollars due to out-migrants have higher incomes than in-migrants. These differences can be also be seen in the changes in median household income and median house values (see Table 1).

Land-use/Land-cover Change

Remote Sensing Data

Yearly composite land cover data in 2001 and 2013 derived from the Moderate Resolution Imaging Spectroradiometer (MODIS) were analyzed to determine land cover changes in Beaver, Wasatch, Grand, and San Juan counties between the study's principal dates. For a discussion on how the MODIS Land Cover Type data are generated, please see Friedl (2010). The MODIS data were analyzed using Google Earth Engine (EE)—an advanced cloud-based spatial geoprocessing platform (https://code.earthengine.google.com; Google 2020; Martin 2019).

Land Use/Land Cover Results

The amount of urban/built-up land remained the same for all four counties in both years (12% in Beaver county; 29% in Wasatch county; 18% in Grand county; <1% in San Juan). However, there were other changes within the four land cover categories that reflect the changing demographics in the counties. Farmland decreased in Wasatch county from 37% in 2001 to about 25% in 2013 while grass/shrubland increased about 4.5% (57.3% to 61.9%). The decrease in farmland and increase in grass/shrubland probably relates to the changing economy from farming to recreation services. This is further borne out by the increase from 3.1% to 11.5% of forested land.

Conversely, Beaver, Grand, and San Juan counties did not have as many land-use/land-cover

changes as much as Wasatch county. Part of this may be due to high percentage of these counties being owned by the federal government when compared to Wasatch County. In Beaver county, farmland decreased from 4.8% to 2.3% and grass/shrubland slightly decreased by 2.2%; in Grand county, farmland decreased from 5.1% to 2.1% and grass/shrubland increased by 5.6%; in San Juan county, farmland decreased by 2.2% and grass/shrubland increased by 4.7% (Figure 3). Grass/shrubland made up the majority of land cover in each county on each date 92.7% in 2001 and 90.5% in 2013 in Beaver county, 84.6% to 89.9% in Grand county, and 92.6% to 97.3% in San Juan county (Figure 4). These large percentages represent the vast amount of undeveloped land in these counties. Forested land increased by 4.8% (2.0% to 6.8%) in Beaver county, 1.6% in Grand county, and 0.8% in San Juan county.

As stated above, a new and specific sense of what the "ideal" rural area looks like may be seen and documented in patterns of land-use/land-cover change. The land-use/land-cover changes in Beaver and Wasatch counties reflect the dichotomous 'bypassed' and 'booming' west noted by Weber (2018).

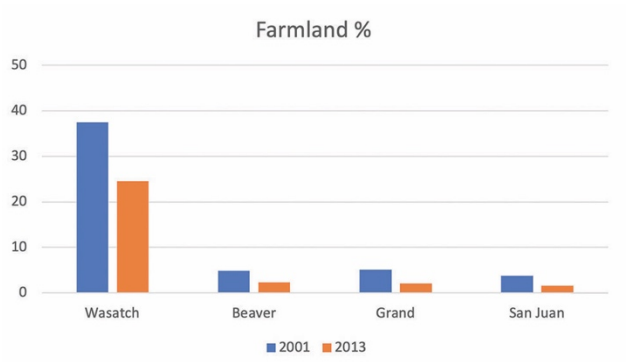

Figure 3. Percentage of farmland in each county in 2001 and 2013.

Nature's Inequalities

At the beginning of his 1999 book, *The Wealth and Poverty of Nations*, David Landes makes the observation that in the process of trying to understand why places are like they are the discipline of geography receives short shrift (Landes 1999, p.5). The reason for the lack of consideration? Geography tends to show unpleasant realities. Our physical world is diverse with some places seemingly and unfairly rewarded and others literally left in the dust. More

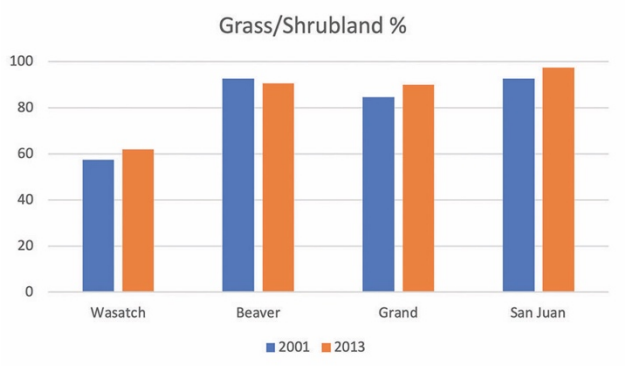

Figure 4. Percentage of grass/shrubland in each county in 2001 and 2013.

important, there is often little we can do to change the set of geographic conditions that make some places better suited to the growth and development of civilization. Because we often believe we are the masters of our own fate, we dislike knowing that geography sets the bounds within which our fate is played out. As previous research has suggested, the principal factors facilitating or mitigating change for the rural Mountain West include the physical environment valued for its recreation potential (or not), government ownership/management of large parts of each county, and economic restructuring away from extractive activities and towards economic activities oriented around recreation, second home owners, and retirement.

This is particularly important in terms of migration. For example, the mobility transition (Zelinsky 1971) provides a broad framework for understanding how and why natural amenities became such a driving force of migration. The idea has its roots in Engle's Law, which demonstrated that as household income increased a smaller proportion of income was spent on basic necessities. As applied to migration, Engle's Law suggests that as a society increases in income and wealth, people's choices concerning where to live also expand. Amenities are now considered as a normal or superior good because of the increased ability to take advantage of geographic differences in environmental conditions. Migration patterns driven by access to natural amenities acts as a natural sorting mechanism based on income.

High amenity regions in the Mountain West region are not ubiquitous. They also tend to have relatively high concentrations of federally owned land, which limits the amount of land available for development. These two factors, along with increases

in demand for access to these places, drive up housing costs. High housing costs limits growth to high income households. It is relatively higher income households who are migrating into Booming and Protected regions and lower income households who migrate to or do not leave the Bypassed regions. This has been and is continuing to create a *New West* geography. A new rural West of increasing income and opportunity inequality.

References

Berry, K. A., Markee N. L., N. Fowler, and G. R. Giewat. 2000. Interpreting what is rural and urban for Western U.S. counties. *Professional Geographer* 52:93–105.

Bryson, J., and W. Wyckoff. 2010. Rural gentrification and nature in the Old and New Wests. *Journal of Cultural Geography* 27 (1):53–75.

ERS. 2017. ERS county typology codes (data file). 2015 Edition. (Washington, DC:USDA Economic Research Service).

Friedl M. A., D. Sulla-Menashe, B. Tan, A. Schneider, N. Ramankutty, A. Sibley, and X. Huang. 2010. "MODIS collection 5 global land cover: algorithm refinements and characterization of new datasets." *Remote Sensing of Environment* 114:168–182.

Google. 2020. *Introduction*. Accessed January 2020. https://developers.google.com/earth-engine/.

Harner, J., and B. Benz. 2013. The growth of ranchettes in La Plata County, Colorado, 1988–2016. *The Professional Geographer* 65 (2):329–44.

Keske, C. H. M., R. P. Bixler, C. T. Bastian, and J. E. Cross. 2017. Are population and land use changes perceived as threats to sense of place in the New West? A multilevel modeling approach. *Rural Sociology* 82:263–90.

Landes, D. S. 1999. *The wealth and poverty of nations*. New York: W.W. Norton.

Larsen, S. C., and C. Hutton. 2012. Community discourse and the emerging amenity landscapes of the rural American West. *GeoJournal* 77 (5):651–65.

Loeffler, R., and E. Steinicke. 2007. Amenity migration in the U.S. Sierra Nevada. *Geographical Review* 97 (1):67–88.

Martin, E.H., R.R. Jensen, P.J. Hardin, A.W. Kisingo, R.A. Shoo, and A. Eustace. 2019. "Assessing changes in Tanzania's Kwakuchinja Wildlife Corridor using multitemporal satellite imagery and open source tools." *Applied Geography* 110:102051. doi:10.1016/j.apgeog.2019.102051.

Narducci J., C. Quintas-Soriano, A. Castro, R. Som Castellano, and J. Brandt. 2019. Implications of urban growth and farmland loss for ecosystem services in the western United States. *Land Use Policy* 86:1–11.

Otterstrom, S. M., and J. M. Shumway. 2003. Deserts and oases: The continuing concentration of population in the American Mountain West. *Journal of Rural Studies* 19 (4):445–62.

Post, C. W. 2013. Heritage, amenity, and the changing landscape of the rural American West. *Journal of Cultural Geography* 30 (3):328–55.

Powers, T. M. 1996. *Lost landscapes and failed economies: The search for a value of place.* Washington, DC: Island.

Powers, T. M., and R. N. Barrett. 2001. *Post-cowboy economics: Pay and prosperity in the new American West.* Washington, DC: Island.

Public Lands Interpretive Association. 2018. Search public lands. Accessed June 3, 2018. http://publiclands.org.

Rasker, R., P. H. Gude, J. A. Gude, and J. van den Noort. 2009. The economic importance of air travel in high-amenity rural areas. Jour*nal of Rural Studies* 25 (3):343–53.

Reisner, M. 1986. *Cadillac desert: The American West and its disappearing water.* New York: Penguin.

Rothman, H. 1998. *Devil's bargains: Tourism in the twentieth-century American West*. Lawrence: University Press of Kansas.

Schaff, C. B., F. Gao, A. H. Strahler, W. Lucht, X. W. Li, T. Tsang, N. C. Strugnell, X. Zhang, Y. Jin, J. P. Muller, P. Lewis, M. Barnsley, P. Hobson, M. Disney, G. Roberts. M. Dunderdale, C. Doll, R. P. d'Entremont, B. Hu, S. Liang, J.L. Privette, and D. Roy. 2002. "First operational BRDF, albedo nadir reflectance products from MODIS." *Remote Sensing of Environment* 83:135-148.

Shumway, J. M., and R. H. Jackson. 2008. Place making, hazardous waste, and the development of Tooele County, Utah. *Geographical Review* 98 (4):433–55.

Shumway, J. M., and S. M. Otterstrom. 2001. Spatial patterns of migration and income change in the Mountain West: The dominance of service-based, amenity-rich counties. The *Professional Geographer* 53 (4):492–502.

Travis, W. R., D. M. Theobald, G. W. Mixon, and T. W. Dickinson. 2005. *Western futures: A look into the patterns of land use and future development in the American West.* Boulder: University of Colorado Center of the American West.

Wan, Z. M., Y.L. Zhang, Q. C. Zhang and Z. L. Li. 2002. Validation of the land-surface temperature products retrieved from Terra Moderate Resolution Imaging Spectroradiometer data. *Remote Sensing of Environment* 83:163−180.

Winkler R, D. R. Field, A. E. Luloff, R. S. Krannich and T. Williams. 2007. Social landscapes of the inter-mountain West: A comparison of 'old West' and 'new West' communities. *Rural Sociology* 72:478–501.

Zelinsky, Wilbur. 1971. The Hypothesis of the Mobility Transition. *Geographical Review* 61 (2):219-249.

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CHANGING PATTERNS OF AGRICULTURE, LAND USE, AND WELLBEING IN THE INTERMOUNTAIN WEST

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Introduction

The rapid growth of population in the western states of Idaho, Montana, Colorado, Utah, and Wyoming over past few decades has attracted larger attention to land use change (Travis 2007) and impacts on agriculture and community wellbeing (Krannich, Luloff, and Field 2011). These five states of the Intermountain West region include the majority of the "interior" West and is dominated by high mountain ranges and interspersed with relatively dry valleys (McNabb and Avers 1994). This region as a whole is experiencing some of the fastest population growth in the United States (Brookings Metropolitan Policy Program 2016; Krannich, Luloff, and Field 2011). Based on news articles and popular culture depictions, the Intermountain West has become known for its oil or gold mines' boom periods and historical cowboy lifestyles, where the fabric and knit of local communities were traditionally woven from planting to harvest (Athearn 1986; Power and Barrett 2001).

In the later part of twentieth century, the region placed itself at the center of major counterurbanization in the country (Manson and Groop 2000). Between 1990 and 2000, the population growth rates in nonmetropolitan exurban population were more than double the nearby metropolitan areas (Berube et al. 2006). However, the recent population growth in nonmetropolitan areas in the region indicates peoples' passion for quality of life and living in this scenic landscape (McGranahan 1999). This change was also driven by growing affluence and expansion of service sector economy, infrastructure development, and spread of information, and communication technology (Smutny 2002; Leinwand et al. 2010). This steady transition led to a post-cowboy economic era (Power and Barrett 2001), in which "historic ties to the land both through work and recreation are transformed" (Nelson, 2001: 406).

Growth in the region is a manifestation of a broader trend of economic, demographic, and social transformations over last several decades in twentieth century America (Krannich, Luloff, and Field 2011). Referred to as the "rural renaissance" in the 1970s, it marked the first time since the Great Depression of the 1930s that there was net population migration into rural regions from urban metropolitan areas (Johnson, 2014). Currently, a huge influx of non-rural people with limited or nonexistent ties to any forms of farm activities or local heritage routed in the nonmetropolitan Intermountain West (Krannich, Luloff, and Field 2011). These "neo-homesteaders" in the region choose to live often in very rural settings by acquiring large parcels of land but do not use it for farm production, but rather for a rural lifestyle. In more colloquial terms, this is a shift from land that produces agricultural goods and services to a "bedroom" community defined by hobby farms and ranches that consume more goods than they produce. This change has also impacted the interactions between land and community (Goldschmidt 1978; Schewe et al. 2012), which have been shown to be accompanied by social controversies and debates (Kruger 2005).

This chapter discusses the changing patterns of land use, agriculture, and impacts on community wellbeing. First, this chapter explains the transition of production landscape to consumption landscapes, and the structural change in agriculture. Second, it addresses the impacts of population growth on community wellbeing. Finally, the chapter highlights the implications of these changes on growth management and planning practice followed by a conclusion section.

Changing Patterns of Land Use and Impacts on Agriculture

Transition from Production to Consumption Landscapes

Traditionally, the nonmetropolitan rural and exurban lands in the Intermountain West were characterized by production landscapes with extractive industries, which include agriculture, fisheries,

forestry, mining, and ranching (Krannich, Luloff, and Field 2011). In contrast, the landscapes that are being used for consumption-oriented purposes are known for consumption, or post-productive landscapes (Ilbery 1998; Schewe et al. 2012). The significance of "rurality" (e.g. the level of rural-ness) plays an important role for this transition from productive to consumptive/post-productive landscape (Halfacree 1994; Beyers and Nelson, 2003). Amenity-driven consumption landscapes invite people who are attracted by and want to pursue rural lifestyles (Schewe et al. 2012; McGranahan 1999). They value enjoying natural amenities, such as scenic mountains or lakes, than any form of production (Rudzitis 1999; Krannich, Luloff, and Field 2011).

Amenity-driven consumption landscape is substantially different from production landscape. From a farming point of view, the productive landscape is more focused on government programs or subsidies to industrialize agriculture and to increase farm outputs. In contrast, consumption landscape de-emphasizes the need and use of rural lands for industrial agriculture and stresses the importance of environmental quality and maintaining local amenities (Ilbery and Bowler 1998). Amenity-based post-productive consumption landscapes is characterized by higher level per-capital land consumption. In 2000, on average the U.S. exurban development occupied seven times as much land as urban and suburban development (Theobald 2005). The ecological impact of exurban development is six times larger than its actual physical footprint (Leinwand et al. 2010). The attractions of unique geographies with natural amenities, investments in and exploitation of natural resources by external capital interests, as well as favorable federal policy, have contributed to this landscape transformation (Beyers and Nelson 2000). In addition to the attractions of scenic, remote, pristine idyllic rural landscapes, in recent years decentralized employment opportunities and improved accessibility, American cultural anti-urbanism and the desire to escape from urban ills, improvement of property and household service technology, and the development of roads and highways have also contributed to this landscape transformation.

Structural Changes and Demographic Impacts on Agriculture

For more than a half-century, the agriculture in the United States experienced restructuring and reorganization (Jackson-Smith 1999; Lobao and Meyer 2001). Agricultural trends in the West are related to broader patterns of structural change in agriculture in the country (Jensen 2005), which include increasing farm output along with consolidation of production in the hands of fewer large commercial operations; increasing average farm size, but with the emergence of a bimodal farm structure characterized by growth in numbers of both very large and very small (hobby or recreation) farms, and a corresponding decline in mid-sized operations; replacement of labor through intensive mechanization; growing levels of capital investment and debt; and growing reliance on off-farm income to support the viability of farm households (Cochrane 1993; Huffman and Evenson 2001; Lobao and Meyer 2001). Now large-scale commercial production operations are dominantly present and more visible in rural America (U.S. Congress, Office of Technology Assessment 1986).

The impacts of population growth on agriculture in the Intermountain West depend on more than the sheer volume of new residents, but are likely mediated by the form and location of new housing construction on the landscape (Ahmed and Jackson-Smith 2019). Since, "rural sprawl" or "exurban" development involves far fewer numbers of people but significantly increased consumption of land per person, they are disproportionately responsible for the conversion of farmland and forests to development each year (Heimlich and Anderson 2005; Riebsame, Gosnell, and Theobald 1996). However, the growth of population in rural and exurban areas in the Intermountain West has been associated with the increase in farm numbers, which are mostly hobby or recreational farms, and a gradual decrease in cropland and farm sales (Ahmed and Jackson-Smith, 2019; Jackson-Smith et al. 2006).

Contested Growth and Impacts on Local Wellbeing

Landscape Change and Impacts on Wellbeing

The emergence of new forms of social interactions and organizations is almost inevitable because of the influx of in-migrants in the nonmetropolitan Intermountain West. It is sometimes not uncommon that the values and morals of long-established rural residents clash with the newcomers (Johnson 2003; Rudzitis 1999; Salamon 2003; Smith and Krannich 2000), which can potentially jeopardize the oppor-

tunities for civic engagement and limit capacities for collective action in pursuits of common interests (Wilkinson 1991). If there are any social, economic, spatial, and psychological barriers for interaction, the quality of life tends to decrease. In many post-productive rural and exurban communities, the principal obstacles to community interaction are the deficiencies in resources for meeting needs and inadequate social infrastructure of services, associations, and channels for collection action (Coupal and Seidl 2003; Wilkinson 1991). Therefore, consumption landscapes often contribute to form further social stratification and class-based interests.

In the consumption landscapes, people are more connected regionally and globally. They often maintain their social and economic ties outside their communities than within their communities. People in amenity-based consumption landscapes tend to alter the very conventional "location-based" notion of community, since they experience more vertical (e.g. extra-local) than horizontal (e.g. community or neighborhood) ties and interactions (Warren 1978). Sometimes this increasing trend of vertical ties and interactions can undermine the traditional values of "spatial closeness" in the community framework.

Since people in amenity-based consumption landscapes are more connected with external actors, the density of acquaintanceship is often lower among people who are living in the same community. Freudenburg (1986) defines density of acquaintanceship as a structural characteristic, which refers to the proportion of people in any given community who know each other. It is one of the important and widely known indicators for community wellbeing. Higher density of acquaintanceship and lower levels of anonymity are expected to increase social cohesion and interaction. On the contrary, low density of acquaintanceship indicates "isolation and estrangement" at the local or collective level (Freundenburg 1986). Surprisingly, the opposite is also true. Extra-local ties (vertical ties) can also contribute to establish and strengthen some local rules or norms, such as basic human or environmental rights. Therefore, Wilkinson (1991) acknowledges that territory might no longer be the primary factor in defining a community, and might even be playing an increasingly less decisive role.

Consumption landscapes can also contribute to positive wellbeing. Many rural communities in the Intermountain West were previously suffering from poverty, lack of health, education, and employment opportunities, and investments along with many other social despairs. In several locations, this rural transformation has provided economic and entrepreneurial opportunities (Krannich and Petrzelka 2003; Krannich, Luloff, and Field 2011; Kruger 2005; Travis 2007; Shaw and Williams 2000; Wall and Mathieson 2006). Therefore, it is not uncommon that amenity-based post-productive consumption land use contributes to increase Durkheim's moral (e.g. interest-based social bonds) and material densities (e.g. increasing employments), which are critical for community wellbeing (Wilkinson, 1991).

Wilkinson (1991) suggests that communities should be defined by the opportunities of social interaction, which is an important determinant of community wellbeing. Since different evidence from research in northern Wisconsin (e.g. Schewe et al. 2012) and the Intermountain West (Krannich, Luloff, and Field 2011) show different outcomes regarding the interaction between new in-migrants, old-timers, seasonal, and permanent residents, it is difficult to reach a conclusion whether post-productive consumption landscapes limit the wellbeing components in the society or do the opposite. As of 2020, both the evidence and theory lead to mixed interpretations.

Changing Patterns of Agriculture and Impacts on Wellbeing

Demographic change and amenity-based post-productive landscapes are the scene of some of the Intermountain West's greatest tensions between development and agriculture. As development spreads, it competes with agriculture for land (Mylott 2009). Counties with the highest rate of population growth are usually associated with the most rapid expansion of developed land (Jackson-Smith et al. 2006). The competition for land from amenity purchasers makes it more difficult for commercial farmers to capture productivity increases by purchasing farmland and expanding their farm holdings. To remain competitive, farmers must intensify their farm operations within the existing land area. Not all farm managers can, or wish to, implement this option though. This means they must choose between selling and moving where land is cheaper, taking off-farm work, or living within the constraints of declining farm income (Barr 2008).

As the structural change in agriculture, including industrialization and mechanization proceeds, farmers usually get increasing contact with suppliers and marketing agents. In this process, people from the

rural communities become more dependent on outside actors, such as big-city banks, and state and federal agencies. Through this, local people experience more vertical ties than horizontal ties. These vertical ties can channel capital, skills and technologies to the local rural community, and can improve to increase moral and material density. However, Goldschmidt (1978) made an alternative argument. He argued that structural change in agriculture would introduce urban values with technology and mechanization into the rural communities. Once urban values are introduced into rural areas, those values create further pressures for more industrialization. In that instance, individuals will adopt specialized functions. Large-scale farming can be a dominant feature. Currently, the number of persons who are independently employed declines along with a gradual decrease of family farm workers.

More than four decades ago, Goldschmidt argued that this process of agricultural restructuring would initiate urbanized rural society, which could potentially substitute a system of social values and bonds based on occupational and monetary standards for the social unity, homogeneity, and personal values (Goldschmidt 1978). Segregation in recreation and religious life, along with poor housing, were the dominant consequences of agricultural restructuring. Therefore, even though structural change in agricultural can provide food surplus and/or capital gains, it likely to contribute to the destruction of the social fabric and support system, at least according to Goldschmidt (1978).

Farm structural change can have significant impacts on farm families, rural communities, and working landscapes. The declining economic viability of mid-sized, full-time commercial farms has led to increased financial and psychological stress for farm operators and family members (Armstrong and Schulman 1990; Belyea and Lobao 1990; Jacob, Bourke, and Luloff 1997), farm structural change has been linked to declines in local spending (Foltz, Jackson-Smith, and Chen 2002; Foltz and Zeuli 2005), and in the quality and types of farm community social ties and patterns of engagement (Goldschmidt 1978; Jackson-Smith and Gillespie 2005). Declining local ownership of farmland decision-making, and control over production and distribution systems contribute to the unfavorable outcomes for the community and the quality of social relationships and interactions within the community (Petrzelka, Ma, and Malin 2013). Changes from farming and ranching to housing development can impact wildlife populations, open space and landscape amenities, and local government finances (Theobald, Miller, and Hobbs 1997).

Contested Growth and Planning Implications

The changes in landscape, land use, agriculture and wellbeing have important implications on growth management and planning processes. In many cases, long-term local residents have utilitarian perspective to growth and development (e.g. more supportive to production as part of their economic gains and living) than newcomers, who often have more conservation-oriented attitudes. These ideological and life-style differences can potentially generate tensions and conflicts in some forms (Salamon and Tornatore 1994; Johnson 2003; Rudzitis 1999; Salamon 2003; Smith and Krannich 2000; Krannich, Luloff, and Field 2011). In addition, this transformation of landscape and agriculture, and changes in community wellbeing, creates complexities for the rural planners in coordinating landscape-level environmental planning and decision-making (Gosnell, Haggerty, and Travis 2006; Schewe et al. 2012).

Farming as a whole is one of the core identities in the Intermountain West. However, the region is losing its prime lands at an alarming rate. For example, in Treasure Valley (Idaho) the urban land area increased by 10%, while at the same period agriculture lands decreased by 5% during 2001-2011 (McSherry et al. 2017). The rate of population growth in the Treasure Valley area is linked to the growing concerns of losing the valley's prime farmlands (Moroney and Castellano 2018). Protecting farmlands and maintaining and improving growth and community wellbeing can be at the core of planning challenges in the region. Structural change in agriculture also makes planning complicated. The interests of commercial versus family farmers, including recreational farmers, are substantially different.

Since both rural and exurban development tend to be fragmented and are often located in areas that lack any serious commitment to public land use planning or zoning, these forms of post-productive growth are often criticized for being less economically and ecologically efficient (Harner and Benz 2013). Various evidence suggest that dispersed rural and exurban development are usually the reason for a larger human footprint on the environment than conventional urban and suburban development (MacLaren et al. 2005; Theobald, Gosnell, and Riebsame1996).

Conclusion

The non-metropolitan rural and exurban landscapes in the Intermountain West are now the place for competing values, needs, desires, and interests. If local resources are not carefully managed, there are always chances for the conflicts of class-based interest in forms of culture clashes, demonstrated by extra-local political ties, which are detrimental for local community wellbeing, resource management, and sustainability at large. Uncontrolled growth driven by market and demand can cause growing income inequality, marginalization, and people with broken dreams.

With careful planning and equitable growth management principles, planners, policymakers, and citizens in the Intermountain West, or broadly, in the American West, should explore the proper mechanisms to address divergent views and promote collaboration and consensus on locally relevant issues so that wellbeing is ensured not just for the people with higher social and economic resources, but also for those who are at the bottom struggling with minimal resources.

References

Ahmed, S. and D. Jackson-Smith. 2019. Impacts of spatial patterns of rural and exurban residential development on agricultural trends in the Intermountain West. *Sage Open* 1-15 doi:10.1177%2F2158244019871037.

Armstrong, P. S. and M. D. Schulman. 1990. Financial strain and depression among farm operators: The role of perceived economic harship and personal control. *Rural Sociology 55* (4):475–493.

Athearn, R. G. 1986. *The mythic west in twentieth century America*. Lawrence, KS: University Press of Kansas.

Barr, N. 2008. The social landscape of rural Victoria. In *Landscape analysis and visualization. Spatial models for natural resource management and planning*, ed. C. Pettit, W. Cartwright, I. Bishop, K. Lowell, D. Pullar, and D. Duncan, 305–25. Berlin and Heidelberg: Springer-Verlag.

Belyea, M. J. and L. M. lobao. 1990. psychosocial consequences of agricultural transformation: The farm crisis and depression. *Rural Sociology* 55 (1):58–75.

Berube, A., A. Singer, J. H. Wilson, and W. H. Frey. 2006. *Finding exurbia: America's fast-growing communities at the metropolitan fringe*. Living Cities Census Series. Washington, DC: Brookings Institute. Accessed May 12, 2012. http://www.brookings.edu/~/media/research/files/reports/2006/10/metropolitanpolicy%20berube/20061017_exurbia.pdf.

Beyers, W. B., and Nelson, P. B. 2000. Contemporary development forces in the nonmetropolitan West: New insights from rapidly growing communities. *Journal of Rural Studies* 16:459-474.

Brookings Metropolitan Policy Forum. 2016. Trends in America's fastest growing, most ruban region. Accessed January 4, 2020. https://www.brookings.edu/wp-content/uploads/2016/07/chp_III.pdf.

Cochrane, W. 1993. *The development of American agriculture: A historical analysis.* Minneapolis: University of Minnesota Press.

Coupal, R., and A. Seidl. 2003. Rural land use and your taxes: The fiscal impact of rural residential development in Colorado. *Agricultural and Resource Policy Report 03–03.* Fort Collins, CO: Colorado State University.

Foltz, J. D., D. Jackson-Smith, and L. Chen. 2002. Do purchasing patterns differ between large and small dairy farms? econometric evidence from three Wisconsin communities. *Agricultural and Resource Economics Review* 31/1:28–38.

Foltz, J. and K. Zeuli. 2005. The role of community and farm characteristics in farm input purchasing patterns. *Review of Agricultural Economics* 27 (4):508–525.

Freudenburg, W.R. 1986. The density of acquaintanceship: An overlooked variable in community research? *American Journal of Sociology* 92 (July):27–63.

Goldschmidt, W. 1978. *As you sow: Three studies in the social consequences of agribusiness.* Montclair, N.J.: Allanheld, Osmun & Co.

Gosnell, H., Haggerty, J.H., Travis, W.R. 2006. Ranchland ownership change in the Greater Yellowstone Ecosystem, 1990–2001: Implications for conservation. *Society & Natural Resources* 19(8):743–758.

Halfacree, K. 1994. The importance of 'the rural' in the constitution of counterurbanization: evidence from England in the 1980s. *Sociologia Ruralis* 34:164–89.

Harner, J. and Benz, B. 2013. The growth of ranchettes in La Plata County, Colorado, 1988-

2008. *The Professional Geographer* 65 (2): 329–344.

Heimlich, R. E. and W. D. Anderson. 2001. *Development at the urban fringe and beyond: Impacts on agriculture and rural land* (ERS Agricultural Economic Report No. 803). Washington, DC: U.S. Department of Agriculture, Economic research Service. Accessed 2 November 2011. http://www.ers.usda.gov/media/536851/aer803_1_.pdf.

Huffman, W.E. and Evenson, R.E. 2001. Structural and productivity change in US agriculture, 1950-1982. *Agricultural Economics* 24: 127–147.

Ilbery, B. and Bowler, I. 1998. From agricultural productivism to post-productivism. In *The geography of rural change*, ed. B. Ilbery, 57–84. Oxon, UK & New York, NY: Pearson Education Limited.

Jackson-Smith, D. 1999. Understanding the micro-dynamics of farm structural change: Entry, exit, and restructuring among Wisconsin family farmers in the 1980s. *Rural Sociology* 64 (1):66–91.

Jackson-Smith, D. and G. W. Gillespie Jr. 2005. Impacts of farm structural change on farmer's social ties. *Society and Natural Resources* 18 (3):1–26.

Jackson-Smith, D., Jensen, E. and Jennings, B. 2006. Changing land use in the rural Intermountain West. In *Population change and rural society*, ed. W.A. Kandel and D.L. Brown, 253–276. Dordrecht: Springer.

Jacob, S., L. Bourke, and A.E. Luloff. 1997. Rural community stress, distress, and well-being in Pennsylvania. *Journal of Rural Studies* 13 (3): 275–288.

Jensen, E. B. 2005. *Outgrowing our roots: Agrarian restructuring in the New West.* MS thesis, Utah State University.

Johnson, K.M. 2003. Unpredictable directions of rural population growth and migration. In Challenges *for rural america in the twenty-first century*, ed. D. Brown and L. Swanson, 19–31. University Park, PA: Penn State University Press.

Johnson, K.M. 2014. Demographic Trends in nonmetropolitan America: 2000 to 2010. In *Rural America in a globalizing world: Problems and prospects for the 201*0*s*, ed. C. Bailey, L. Jensen, and E. Ransom, 311–329, Morgantown, WV: West Virginia University Press.

Krannich, R.S., Luloff, A.E. and Field, D.R. 2011. *People, Places and Landscapes: Social Change in High Amenity Rural Areas*. Dordrecht: Springer.

Krannich, R., and Petrzelka, P. 2003. Tourism and natural amenity development: Real opportunities? In *Challenges for rural America in the twenty-first century*, ed. D. L. Brown and L. E. Swanson, 190–199. University Park: Pennsylvania State University Press.

Kruger, L.E. 2005. Community and landscape change in southeast Alaska. *Landscape and Urban Planning* 72:235–249.

Leinwand, I.I.F., D.M. Theobald, J. Mitchell, and R.L. Knight. 2010. Landscape dynamics at the public-private interface: A case study in Colorado. *Landscape and Urban Planning* 97: 182–93.

Lobao, L. and Meyer, K. 2001. The great agricultural transition: Crisis, change, and social consequences of twentieth century U.S. farming. *Annual Review of Sociology* 27:103–24.

MacLaren, C., K. Kimball, G. Holmes, and D. Eisenbeis. 2005. Too many homes on the range: The impact of rural sprawl on ranching and habitat. Accessed 12 October 2013. www.friends.org/sites/friends.org/files/reports/too_many_homes.pdf.

Manson, G.A., and R.E. Groop. 2000. U.S. intercounty migration in the 1990s: People and income move down the urban hierarchy. *The Professional Geographer* 52(3):493–504.

McGranahan, D. A. 1999. Natural amenities drive rural population change (No. 781). Economic Research Service, U.S. Department of Agriculture, Washington, DC.

McNab, W. H. and P. E. Avers. 1994. Ecological subregions of the United States: Section descriptions. Administrative Publication WO-WSA-5. U.S. Department of Agriculture, Washington, DC.

McSherry, L., Narducci, J., Sprague, C., Costa, A., Brandt, J., Fragkias, M., Schneider, J., and Benner, S. 2017. Urban growth in Treasure Valley Idaho. Accessed December 11, 2019. http://arcg.is/1DC08f.

Moroney, J. I., and Castellano, R.S. 2018. Farmland loss and concern in the Treasure Valley. *Agriculture and Human Values* 35:529–536.

Mylott, E. (2009). Urban-rural connections: A review of literature. Accessed November 12, 2012. http://hdl.handle.net/1957/10574.

Nelson, P. B. 2001. Rural restructuring in the American West: Land use, family and class discourses. *Journal of Rural Studies* 17:395–407.

Petrzelka, P., Ma, Z., and Malin, S.A. 2013. The elephant in the room: Absentee landowners and conservation management. *Land Use Policy* 30: 157–166.

Power, T.M. and Barrett, R. 2001. Post-cowboy economics: Pay and prosperity. In *The new American West.* Washington, Covelo, and London: Island Press.

Riebsame, W. E., H. Gosnell, and D. M. Theobald. 1996. Land use and landscape change in the Colorado Mountains I: Theory, scale, and pattern. *Mountain Research and Development* 16 (4): 395–405.

Rudzitis, G. 1999. Amenities increasingly draw people to the rural West. *Rural Development Perspectives* 14:9–13.

Salamon, S., and Tornatore, J.B. 1994. Territory contested through property in a midwestern post-agricultural community. *Rural Sociology* 59: 636–654.

Salamon, S. 2003. *Newcomers to old towns: Suburbanization of the heartland.* Chicago, IL: University of Chicago Press.

Schewe, R.L., Field, D.R., Frosch, D.J., Clendenning, G. and Jensen, D. 2012. *Condos in the woods: The growth of seasonal and retirement homes in northern Wisconsin.* Madison, WI: The University of Wisconsin Press.

Shaw, G. and Williams, A. 2000. *Tourism, leisure, and recreational series: Tourism and sex.* London: Pinter.

Smith, M.D. and Krannich, R.S. 2000. Culture clash revisited: Newcomer and long-term residents' attitudes towards land use, development and environmental issues in rural communities in the Rocky Mountain West. *Rural Sociology* 65(3): 396–421.

Smutny, G. 2002. Patterns of growth and change: Depicting the impacts of restructuring in Idaho. *The Professional Geographer* 54(3):438–53.

Theobald, D.M. 2005. Landscape patterns of exurban growth in the U.S.A. from 1980 to 2020. *Ecology and Society* 10 (1):32–66.

Theobald, D. M., J. R. Miller, and N. T. Hobbs. 1997. Estimating the cumulative effects of development on wildlife habitat. *Landscape and Urban Planning* 39:25–36.

Travis, W. R. 2007. *New geographies of the American West: Land use and the changing patterns of place*. Washington, Covelo, London: Island Press.

U.S. Congress, Office of Technology Assessment. 1986. *Technology, public policy, and the changing structure of American agriculture*. U.S. Government Printing Office, Washington, DC.

Wall, G. and Mathieson, A. 2006. *Tourism, change, impacts, and opportunities*. Essex: Pearson.

Warren, R.L. 1978. *The community in America*. University Press of America: Lanham, New York and London.

Wilkinson, K. 1991. *The community in rural America*. Middleton, Wisconsin: Social Ecology Press.

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URBAN GEOGRAPHIES OF DENVER

Denver, Colorado. Photo by David Mark.

METROPOLITAN DENVER: FROM 'QUEEN CITY OF THE PLAINS' TO 'MILE HIGH CITY'[1]

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The headline of the *Denver Post* on September 18, 2015, read: "Denver is flourishing." In fact, the beginning of the twenty-first century marks a high point in the history of Denver, Colorado. Population is booming, with a diverse influx of young millennials, older baby boomers, and new immigrants from across the globe. The region has a strong and diversified economy, resulting in rising median household incomes that are 25 percent higher than the national average, and a local poverty rate and unemployment rate well below national averages (Olinger 2015). The city celebrated its sesquicentennial anniversary in 2008, at a time when Denver was acquiring newfound national and international recognition as a successful city. New transportation infrastructure developments, including new light rail lines, and exciting growth of mixed-use high-density housing developments illuminate the city's attitude toward eco-friendliness and growth consciousness. Like other cities of the New West, Denver offers a variety of lifestyle choices in a place where the Old West mystique is mixed with the urban and high tech, where people can encounter both rugged landscapes alongside ideal urban or suburban lifestyles. And on those days where sunny skies, mild weather, and a clear view of the nearby Rocky Mountains fill the landscape, Denverites might feel the sentiment reflected in publisher Frederick G. Bonfils's oft-repeated phrase from the 1930s: " 'Tis a privilege to live in Colorado" (Leonard and Noel 1990, 169).

A variety of reasons might help explain why Denver seems to be flourishing. Denver has benefited from strong civic leadership, an early and successful spirit of entrepreneurialism, a legacy of charitable philanthropy, a favorable location with proximity to an abundance of natural resources, an enviable mild and sunny climate, quick access to mountain-based recreation, and successes in regional collaboration, including planning for future urban growth.

But at the same time Denver has also experienced many challenges, some quite common to other growing cities. Economic inequalities and social segregation have persisted, and communities have been marginalized or displaced. Rapid population growth is sprouting ongoing traffic congestion and sprawl, and metropolitan political fragmentation stymies regional progress on pressing issues. Air pollution has spoiled the region's crisp, clean air; surrounding land degradation is resulting from overuse for resource extraction and agriculture production; and urban development is encroaching into nearby open space, which continues with ongoing growth.

These successes and challenges are both Denver's legacy and its future. The purpose of this chapter is to provide a broad overview of Denver, Colorado by highlighting these successes and challenges through a variety of themes from a geographic perspective. Here we focus on Denver's evolving identity from the early "Queen City of the Plains" to the more contemporary "Mile High City."

The Queen City of the Plains

The city of Denver was founded on the western frontier of the United States in 1858. As it did with San Francisco, the discovery of gold turned Denver into an "instant city." It emerged suddenly from a rapid influx of disparate groups of individuals seeking personal riches. Isolated in the wilderness, with little common history or traditions, early Denverites found social cohesion through their common vision of pursuing individual economic freedom. It was an unlikely city, located at the convergence of the impenetrable Rocky Mountains and the eastern plains, once perceived as uninhabitable and unfit for cultivation. But upon the founding of Denver City in 1858, William H. Larimer Jr. predicted, "Everyone will soon be flocking to Denver for the most picturesque country in the world, with fine air, good water, and

[1] This chapter is an excerpt from the Introduction in Andrew R. Goetz and E. Eric Boschmann. 2018. *Metropolitan Denver: Growth and Change in the Mile High City*.

everything to make man happy and live to a good old age" (Leonard and Noel 2016, 12-13). Within a single generation Denver overcame its isolation in the frontier and transformed into a bustling city connected to the national market economy, becoming the Queen City of the Plains, an urban oasis in the wilderness of the Wild West (Barth 1975). Numerous factors led to the early success and survival of Denver.

While it first existed as a dusty, brawling mining camp and supply center along the South Platte River, Denver quickly established itself as the finance, transportation, and communications hub for the Rocky Mountain region. The vast hinterland of natural resources, including minerals from the mountains and cattle and sugar beet agriculture from the plains, flowed through Denver, where they were processed, refined, and loaded onto trains bound for distant markets. The Denver and Pacific Railroad was the first linkage to the transcontinental Union Pacific Railroad in 1870, ensuring the city's vital role as a transportation center and stimulating many more railroad lines and communications investments. Denver's financial stability and regional importance was further enhanced when the federal U.S. Branch Mint was established in 1863 and the First National Bank of Denver opened in 1864.

Great entrepreneurial leadership from William Larimer, William Byers, John Evans, Horace Tabor, Eben Smith, Jerome Chaffee, David Moffat, Walter Cheesman, and many others modeled the spirit of laissez-faire capitalism, which offered growth and prosperity across the region. As owners of the mining, railroading, banking, newspaper publishing, merchandising, or warehousing industries, they worked to establish a strong local economy that serviced the regional resource extraction activities of the hinterland, where Denver's role as "gateway to the mountains" was solidified. Their entrepreneurial leadership helped secure outside investments and diversification of the economic base that ultimately enabled the city to withstand a long series of boom-and-bust economic cycles.

At that time Colorado was branded the "Switzerland of America," initiating a robust tourism industry centered on the majestic Rocky Mountains, and all the scenery, splendor, and recreation they offered. For early Denver, the attractive climate generated a significant population influx of so-called health seekers. The tuberculosis epidemic of the nineteenth and early twentieth centuries sent sufferers ("consumptives") and their families from their homes in eastern industrial cities to locations in the West with more favorable climate. It was believed that Denver's dry climate, high elevation, clean air, mild weather, and abundant sunshine provided therapeutic relief to consumptives. Eventually tens of thousands of health seekers descended upon Colorado, stimulating an extensive health industry of hospitals and relief societies.

The rapid economic growth and prosperity of this urban frontier came with tragic exploitation. Mining and smelting wastes polluted nearby land and water supplies, and overuse of dry agricultural lands exacerbated the challenges of drought years. Native Americans were "vanquished" from the plains, as justified by racist ideologies, in order to remove obstacles of progress in the commercial agricultural activity that diversified Denver's economy (Brosnan 2002). The Sand Creek Massacre of 1864 was the most horrific anti-Indian event in which over 160 Cheyenne and Arapaho, mostly women and children, were killed during a nighttime military ambush led by U.S. Army colonel John Chivington.

In the city itself, many persons who never benefited from capitalist opportunity suffered marginalization or exploitation; others became the unlucky ones, losing everything during periods of crushing economic busts. In the midst of this poverty of the early days, many individuals started charities to give help to others (Speer and Rodriguez-McGill 2013) including Elizabeth Byers' Ladies Union Aid Society, Ella Vincent's Ladies Relief Society, and Frances Wisebart Jacobs' creation of a "community chest" that eventually became the United Way. And as in most cities, Denver's philanthropic legacy helped provide for people in need and build a better society. For example, Helen and May Bonfils, daughters of *Denver Post* owner Frederick G. Bonfils, shared their wealth with Denver by funding the Church of the Holy Ghost, the Denver Center for the Performing Arts, hospitals, health clinics, and the ongoing legacy of a $100-plus million foundation for arts and creativity.

The Denver of today also exists in part from a long legacy of great civic leadership determined to keep Denver beautiful. At the beginning of the twentieth century Denver was a dirty city, with limited street and sanitation planning, and a dearth of green spaces and city parks. Influenced by the 1893 Columbian Exposition, Mayor Robert Speer sought to bring the City Beautiful vision of order and beauty to Denver and make it a "Paris on the Platte" or "Rome

of the Rockies." His imprints on the urban landscape are many, including the Civic Center, an open park space downtown surrounded by government buildings, museums, and monumental neoclassical architectural structures; the Auditorium Arena (today the Ellie Caulkins Opera House) built to bring culture to the masses with free plays and operas; and numerous parks (e.g. City Park, Cheesman Park) and parkways radiating out from the city. And beyond the city Mayor Speer sought to preserve the natural beauty of the mountain landscape and make it more accessible to Denver's residents. This culminated in the creation of the Denver Mountain Parks, a collection of twenty-two parks over fourteen thousand acres owned and maintained by the City and County of Denver, but completely in the mountains and outside the municipal boundaries. This includes the iconic Red Rocks Park and Amphitheater (Figure 1). This vision of keeping Denver beautiful and providing access to nature remained a key theme of civic leadership over the next one hundred years and beyond.

Figure 1. Red Rocks Amphitheatre, a Civilian Conservation Corps (CCC) project completed in 1941. Photo by authors.

The Mile High City

Another enduring theme of Denver's past, present, and future is rapid population growth and the accompanying challenges. This is particularly true in Denver since the mid-twentieth century as continuous debates center on how to balance the economic benefits of growth with the impacts on the environment and regional quality of life. Also during this period, a new identity of Denver emerged, one that moves beyond its Wild West cow town roots. The Mile High City nickname has branded the city as a place set apart, even as it moves toward becoming more globally connected and an attractive destination city.

For much of urban America the end of World War II was a major turning point. In Denver, "massive federal spending, an influx of newcomers, and a pent-up demand for new cars and new housing led to a boom that would change this drowsy cow town into a sprawling metropolis" (Leonard and Noel 1990, 235). Military and federal expansion in Denver led to significant job growth in the area. And suburbanization trends coupled with the in-migration surge expanded the Denver region further into the surrounding suburbs and exurbs.

This metropolitan-wide residential reshuffling began to reveal racial tension in Denver, a place people had perceived to be free of the segregation and urban crisis issues experienced in other U.S. cities. But underneath, Denver had long been a socially fractured city. Many Native American and Spanish Mexican communities in the area predated the establishment of Colorado but were marginalized after the founding of Denver. By the 1920s more Latinos/Hispanics and African Americans migrated seeking economic opportunities. It was the 1970s school desegregation fights that exposed the depths of Denver's racial divide. The 1973 U.S. Supreme Court case *Keyes v. Denver School District No. 1* not only set a precedent for busing desegregation in northern states, but it also articulated that Denver was a tri-racial city—a reality previously unacknowledged. A strong antibusing movement in the region led to the 1974 Poundstone Amendment to the Colorado Constitution, effectively ending Denver's ability to annex land from suburban counties.

Denver faced another population growth surge during the Sun Belt migration trend of the 1970s and early 1980s. At this time Denver's specialization in the industries of banking, oil and mineral extraction, federal services, telecommunications, and transportation escalated the city to the ranks of the largest U.S. metropolitan areas through its position as the major regional commercial center for the plains and the Rocky Mountains. The city's booming oil economy even became the setting of the popular 1980s American prime-time soap opera *Dynasty*, which revolved around the oil wealthy Carrington family. Despite this growth, Denver remained perceived by many as a sleepy cow town out on the western frontier. It also faced many of the challenges similar to other Sun Belt cities, including poverty and segregation, economic recessions due to resource

base dependencies, or the negative impacts of population growth and development including suburban sprawl, traffic congestion, pollution, environmental degradation, or the loss of traditional regional characteristics and identity. And, tragically, Denver was also the site of two of the worst mass shootings in the United States: Columbine High School in 1999 and the Aurora Theaters in 2012.

The substantial population growth, expansion of the regional freeway system, and continued outward sprawl has not pleased everyone. Locals lamented the loss of their quiet and slower-paced city that once existed and targeted their frustration at the city's numerous transplants from elsewhere. The undercurrents of antigrowth disdain have played out in local area bumper stickers. Some, with a green-and-white silhouette of the mountains, simply say: "No Vacancy" or "Native" (Figure 2). And others, with anger directed at what seemed an adoption of California-style highway and car culture, read, "Don't Californicate Colorado." An environmental consequence of Denver's growth was a massive air pollution problem worsened by a booming automobile culture resulting in a ubiquitous brown cloud of haze hanging over the city during winter months. In 1987—for all the world to see—a two-page photo appeared in *National Geographic* magazine of Denver's congested highways with the skyline barely visible through the haze (Grove, Spiegel, and Bond 1987). And after the Denver Broncos football team lost the 1989 Super Bowl, a CBS sportscaster quipped that Denver had "never been No. 1 in anything —but carbon monoxide" (Brooke 1998). Much to the dismay of city leaders and boosters, Denver and its dismal air quality became a national joke.

By the 1990s city leaders had several negative images to overcome: Denver's enduring legacy as a sleepy and unsophisticated cow town, its infamy as a dirty-air suburban-and-highway mush trending toward a Little Los Angeles, and Denver as merely the gateway—or worse, the "locker room"—to the Rocky Mountains (Edwards 2014, 14). Thus began a determined push to make Denver an attractive city to live in and a destination for tourism and business.

Major urban revitalization and megaprojects focused on Denver as easy to get to, easy to get around, competitive, cool, and livable, with numerous choices for entertainment, culture, and recreation. Mayor Federico Peña's (1983–91) "Imagine a Great City" vision resulted in many transformative infrastructure projects, including a new convention center, the Coors Field baseball stadium, new libraries, and the Denver International Airport (DIA). The 2004 FasTracks plan began the buildout of 122 miles of new rail transit in the region. And Dana Crawford's tireless work as preservationist and developer saved much of Lower Downtown Denver from urban renewal demolition, revitalizing old streets and buildings into vibrant and economically prosperous gathering spaces such as Larimer Square and Union Station. In fact, former Denver mayor and Colorado governor John Hickenlooper noted that the impact of Crawford is immeasurable, as she "single-handedly saved lower downtown Denver" (McPhee 2015, 221).

Figure 2. Two anti-growth bumper stickers observed in the Denver metropolitan area. Photo reproduction by authors.

The remaking of Denver into a destination city also created it into a lifestyle city, attracting imaginations of Americans as one of the most enviable places to live. For decades the Rocky Mountains of Colorado held national allure. The popularity of folk musician John Denver, who "embodied Colorado's recreational-environmental ideal," highlighted to mass audiences the majesty of the Rocky Mountains and the human endeavor to escape the city and engage nature. Eventually the tourism activities of camping, hiking, skiing, or white-water rafting stimulated a trend of living where tourists play and shifted Denver-as-urban-gateway to Denver-as-residential-vacationland (Philpott 2013, 239). This New West city (Figure 3) offered opportunities to live, work, and play in a bustling urban center with quick access to endless amenities of recreation, environment, scenery, and entertainment out in the vast Colorado backyard. It became a place where people visited and never wanted to leave. And to counter the antigrowth sentiment, bumper stickers of newcomers staking

Figure 3. National Western Stock Show opening parade in downtown Denver. Photo by authors.

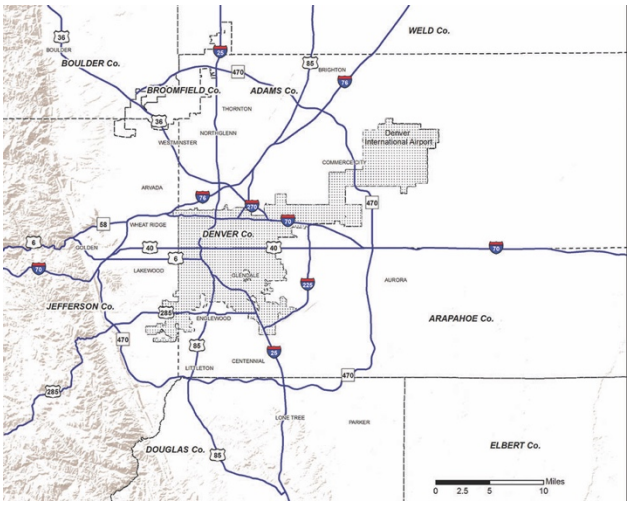

Figure 4. Map of the central portion of the Denver metropolitan area. Created by authors and Paul Donegan.

their own claim to Colorado appeared, proclaiming: "I'm not a NATIVE, but I got here as fast as I could!"

Denver's Future

Future population growth is perhaps the greatest challenge ahead for the Denver region. Colorado added 100,000 new residents in a twelve-month period (July 2014–July 2015) representing a 1.89% growth rate, twice the national average of 0.79%. Most in-migrants are 18 to 34-year-olds with bachelor's degrees who come from California, Texas, Florida, Arizona, and New York (Kemp 2015). They settle in the Denver area drawn not simply to the nearby skiing, urban hiking, or microbreweries, but also by the many opportunities in a strong regional jobs market (Campoy and Frosch 2015). The 2010 Denver metropolitan area (Figure 4) population of 2.6 million will increase to 3.4 million in 2030, and 4 million by 2040.

This future growth poses many challenges for the Denver region. In recent years the region has increased its alternative and public transportation options, including light and commuter rail lines, bus rapid transit, and bicycle and pedestrian friendly infrastructures. But for many, Denver remains a very car-dependent place. And automobile usage and traffic congestion continue to rise. Denver's booming real estate market has resulted in numerous problems of housing inequities, including gentrification-driven displacement from historic neighborhoods, increased homelessness, too few affordable housing options, and decreased proximity to jobs and public transit.

The population growth also places greater pressure on protecting the natural environment and managing scarce resources. Growth management agreements have the potential to direct the location and density of new urban developments. But suburban and exurban sprawl will likely continue and further encroachment into the mountain foothills will expand the wildland-urban interface. And with regard to the perennial scarcity of water in a semiarid region, there is a paradox of living in the West: here large populations are supported by massive water infrastructures (including dams, reservoirs, tunnels, or ditches), but those infrastructures disrupt the very ecosystems and landscapes that lure people to live in the West (Limerick and Hanson 2012). Ultimately the water resource challenge may possibly be the most pressing issue in the upcoming decades in Denver and all Colorado.

Perhaps no city symbolizes the American West more than Denver, Colorado. It was founded in a rush for gold, it emerged on the frontier as a mining and agricultural town, and grew into a major metropolis, a destination city, and a hub for tech, energy, and environmental recreation industries. But like most cities, its story is one of continual evolution through the forces of inevitable growth and change. We hope this chapter has highlighted these forces in what the poet Walt Whitman first described as "this curiously attractive region" (Whitman 1887).

References

Barth, G. 1975. *Instant Cities: Urbanization and the Rise of San Francisco and Denver*. New York: Oxford University Press.

Brooke, J. 1998. Denver seeing the light past its 'Brown Cloud'. *New York Times*, April 21, A10.

Brosnan, K. 2002. *Uniting Mountain and Plain: Cities, Law, and Environmental Change Along the Front Range*. Albuquerque: University of New Mexico Press.

Campoy, A., and D. Frosch. 2015. Denver job market lures millennials. *Wall Street Journal*, July 23.

Edwards, S. 2014. Full steam ahead for downtown Denver. *National Geographic Traveler*, August–September.

Grove, N., T. Spiegel, and W. Bond. 1987. Air: An atmosphere of uncertainty. *National Geographic Magazine,* April.

Olinger, D. 2015. Denver is flourishing. *Denver Post*, September 18.

Kemp, R. 2015. *Colorado Migration in 2013*. State Demography Office, Colorado Department of Local Affairs.

Leonard, S., and T. Noel. 1990. *Denver: Mining camp to metropolis*. Boulder: University of Colorado Press.

———. 2016. *A short history of Denver*. Reno: University of Nevada Press.

Limerick, P., with J. Hanson. 2012. *A ditch in time: The city, the West, and water*. Golden, CO: Fulcrum.

McPhee, M. 2015. *Dana Crawford: 50 years saving the soul of a city*. Denver: Upper Gulch.

Philpott, W. 2013. *Vacationland: Tourism and environment in the Colorado High Country.* Seattle: University of Washington Press.

Speer, Julie (director and writer), Mariel Rodriguez-McGill (writer). 2013. "Colorado Philanthropy." In History Colorado and Rocky Mountain PBS (producers), Colorado Experience. Denver: Rocky Mountain Public Broadcasting Network.

Whitman, W. 1887. *Specimen days in America*. London: Walter Scott, 227; cited in Leonard and Noel 1990, 123.

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GENTRIFICATION AND DENVER'S HISPANIC PAST

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In the public imaginary, Colorado exists as a notoriously white space. Character Tracy Jordan of the TV series *30 Rock* perhaps puts it most bluntly: "Diabetes…is a white myth, like Larry Bird or Colorado!" Growing up in Denver, I recall house-guests commenting on the lily-white appearance of the city. Yet Denver, its metropolitan area, and Colorado at large have always been multiracial spaces. They are, however, highly segregated, and by design. This article argues that as Denver has become progressively more affluent and demographically white, the city's centrally-located historically Hispanic[1] neighborhoods have been used as laboratories for seemingly every extant modality for city government-led displacement, to the point that Denver now leads the nation in Hispanic displacement via gentrification (Richardson et al. 2019).[2] At the same time, the city's efforts have time and again resulted in the equal and opposite reaction of community activism. Targeted, city-led displacement and Hispanic political organizing exist in tension with one another in Denver.

One anomaly that has made necessary such a variety of technologies for displacement is that Denver's Hispanic neighborhoods have historically had high rates of homeownership. In the northeast Denver communities of Globeville, Elyria, and Swansea (Figure 1), which are currently seeing surging property values and displacement, the Cross-Community Coalition found that in 2017, 51% of homes were owned, and that 70% of homeowners' tenure exceeded ten years. "A notable data point," they wrote, "is the 83% of property owners who identify as Hispanic. This is almost double the national average of homeownership rates for Hispanics, and nine percent higher than nationwide ownership rates for non-Hispanic whites" (CdeBaca 2017).

These high homeownership rates are largely an effect of the abiding, artificial devaluation of the city's 1934 redline (Arellano 2016; see Figure 2), which in turn created a rent gap (Smith 1987) that, as the economy of the city has grown, has made the

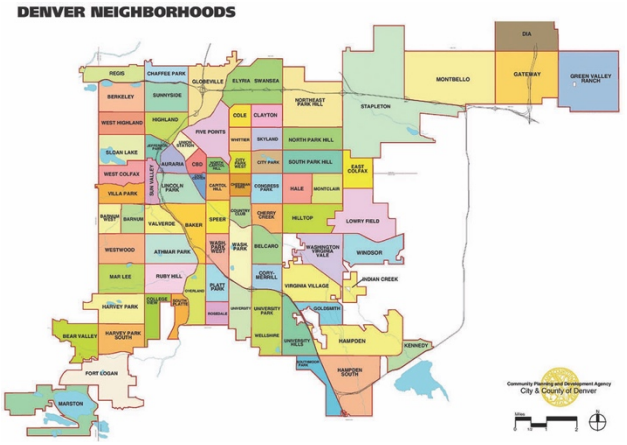

Figure 1. City of Denver neighborhood map (http://www.denverhomesonline.com/files/1313/2917/6043/City_Of_Denver_Neighborhoods_Proper.jpg).

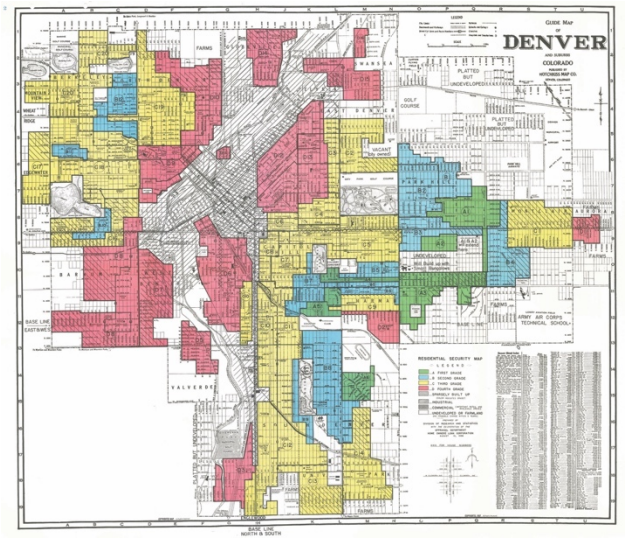

Figure 2. Denver Redlining Map (*Mapping Inequality*, https://dsl.richmond.edu/panorama/redlining/#loc=14/39.725/-105.027&city=denver-co&text=bibliograph).

neighborhoods attractive for developers. Yet unlike more renter-dominated cities (Greenberg 2017), Denver could not be gentrified by rising rents alone.

This article, arranged geographically—think of it as an academic's field guide—aims to provide tools for seeing and understanding targeted displacement in

three neighborhoods of the contemporary Queen City of the Plains. Adding a historical layer to the visitor's eye, it aims to draw attention to Denver's long history as a non-white space, as well as to consider the costs of its current transformative growth.

Background

In its articulation of whiteness and power, the space we now know as Colorado has differed from its surroundings since it was introduced as a territory in 1861. Colorado gained its territorial status after a significant population increase in the wake of its 1858 Gold Rush. Whereas Utah and New Mexico spent 45 and 61 years as territories, respectively, due largely to the fact that they were demographically and politically controlled by minority groups—Mormons and Hispanics—"Colorado…retained close business and social connections with the American East" (Lamar 2000, 3) and was "a far cry from the tradition-bound and caste-conscious territory of New Mexico" (Lamar 2000, 188). That eastern- and commerce-mindedness fast-tracked the territory to statehood in a matter of fifteen years.

The state is also startlingly different from its neighbors in the relative absence of Native presence, both demographically and culturally. This is a result of concerted warfare against the state's native peoples. The formation of Colorado Territory involved re-negotiating the Treaty of Fort Wise with the Arapahoe and Cheyenne peoples. Though only ten chiefs signed the treaty, the U.S. nevertheless moved forward with their relocation to a reservation near Sand Creek, where there was neither arable land nor buffalo (Clemmer-Smith et al. 2014). President Lincoln appointed William Gilpin, a veteran of the Seminole Wars and member of John C. Frémont's continental divide expedition, to be Colorado's first territorial governor. Gilpin's administration's major mandate was to maintain the state for the Union; Gilpin created the 1st Regiment of Colorado Volunteers in 1861, and in 1862 appointed Major John Chivington as its head. When John Evans succeeded Gilpin as governor, he prioritized Indian raids as a major purpose of the Colorado Volunteers—climaxing with the "running slaughter" of the 1864 Sand Creek Massacre (Klinkenborg 2000).

As Anglo settlers waged war against the region's native peoples, Spanish-speaking communities moved northward from New Mexico into southern Colorado, which until then had been occupied by Ute peoples considered hostile. In 1852, those settlers established the town of San Luis, now considered the oldest town in Colorado (Colorado Encyclopedia 2016). Members of these Spanish/Mexican communities who were made U.S. citizens by the Treaty of Guadalupe Hidalgo have been called "treaty citizens" (Lozano 2018). They began to migrate from New Mexico and southern Colorado to Denver and northern Colorado around 1870, with seasonal movement to coal mining camps and sugar beet fields, punctuated with either return to villages or temporary settlement in the poor sections of Denver, Fort Collins, and Greeley during the winter. This migration increased with the Great Depression (Deutsch 1987, Nostrand 1992, Standish 2002). Additionally, between 1900 and 1930, 45,000 people came to Colorado from Mexico to work in the sugar beet fields, lured by the Great Western Sugar Company at the same time as they were pushed out by the instability of the Mexican Revolution (Standish 2002; Chase 2011).

Later in the twentieth century, push factors overtook pull: between 1960 and 1990, between 50% and two thirds of the rural Hispano population of southern Colorado migrated to cities, precipitated by the collapse of independent sheep-raising after the enclosure of the Sangre de Cristo Land Grant's common lands (Peña 1998); many families in the region sold their land during the Vietnam War, whose draft rendered the region's villages "ghost towns" (Garcia 2010). At the same time, postwar white flight to the suburbs made it possible for Hispanic families to buy houses in neighborhoods once occupied by the white immigrant working class, such as Italians and Slavs (Doeppers 1967). With the end of the Bracero Program and the progressive tightening of immigration laws starting with 1965's Hart-Cellar Act, increasing numbers of permanent immigrants from Mexico have joined these communities as well, as circular, seasonal undocumented migration has become essentially impossible.

Auraria: Urban Renewal

On the southern edge of downtown Denver now sits the Auraria Higher Education Center, home to Metropolitan State University of Denver, the University of Colorado Denver, and Community College of Denver. While these campuses are important regional learning centers, the campus also carries the legacy of its creation through city-led urban renewal.

Auraria was established as its own city by a group of miners in 1858, several weeks ahead of Denver, its competitor on the other side of Cherry Creek. The two towns merged in April of 1860. Auraria became a neighborhood of working-class Central and Eastern European immigrants, but by 1920, electric streetcars and automobiles had opened up neighborhoods further from downtown to those communities, and Auraria became predominately populated by Hispanic arrivals from southern Colorado, northern New Mexico, and northern Mexico, becoming majority Hispanic by 1950 (Page & Ross 2017; Bryson 2018).

By the middle of the century, city officials were troubled by Auraria's Hispanic community, and marked it as "blighted," citing overcrowding concerns. When the South Platte River flooded in June of 1965, the city set in motion a large-scale redevelopment for the site. Matching federal HUD money with a bond approved by 52% of Denver voters, the city cleared the neighborhood—a total of 840 people—to make way for the campus. A 1969 survey conducted by the Denver Urban Renewal Authority found that 89% of Auraria's households were Hispanic, 82% had not completed high school, and that the average household income was $3,978, compared to an average U.S. nonfarm household income of $13,270 (Page & Ross 2017).

Relocations were complete by 1972; Auraria Campus was completed by 1976 (Page & Ross 2017). Though the neighborhood was not successful in fighting it, Auraria's clearing led to multiple significant political formations in Denver and beyond. Firstly, led by Father Peter Garcia of St. Cajetan's Church, Aurarians formed the Auraria Residents Organization, aiming to stop their displacement. That organization later gave rise to a variety of other Hispanic political formations in the city (Bryson 2018)—organizing which would become key to the fight over the Northside described below. One of them, the Hispanic students' group at Metropolitan State College, also gave rise to the creation of the nationwide Chicano students' organization MEChA (Movimiento Estudantil Chicano de Aztlán) (MEChA MSC 1979). The clearing of Auraria was also a turning point for a nascent historic preservation movement in downtown Denver: after the Auraria bond passed, activists worked to ensure the preservation of a block of Victorian homes from the original neighborhood, St. Cajetan's church, and the Tivoli Brewery, all still part of the Auraria Campus.

Finally, two decades after the neighborhood was cleared, under pressure from the displaced community, the Higher Education Center brought one of the city's key promises to the community to fruition: scholarships for displaced residents, their children, and grandchildren (Bryson 2018; UCD 2020). These scholarships have made the Auraria campus into a tool of social mobility for the people its creation affected. As its clearance ages deeper into the past, however, the scholarship is likely reaching its last generation of students. Meanwhile, as northeastern Denver faces displacement—described below—its residents are looking to the Displaced Aurarian Scholarship as a model for a similar reparation program (Allen 2019).

Highland-Highlands-Northside: Chicanismo vs. Gentrification

Like Auraria, Northwest Denver was initially platted as its own tranquil, elite suburb—"Highland" or "Highlands"—where liquor licenses were made so prohibitively expensive as to foster an effective prohibition (Wiberg 1976). As the city grew, the area followed Auraria in becoming a predominately working-class white neighborhood, with Italians as the majority group through the 1930s and 40s.

Because of postwar white flight, by 1950, Italians made up just 12% of the neighborhood's population. By 1970, compounded by exodus from the neighborhood due to the construction of I-70 (finished in 1964), they made up less than six percent (Hunt 1999). From 1970 to 2000, then, Highland was over 60% Hispanic (Hunt 1999). The neighborhood came to be known as "Northside," defined by the catchment of Denver's North High School (Mejia 2014). Between 2000 and 2010, however, that figure dropped precipitously, to 37%—while the median home value rose from $100,000 to $450,000 (Denver Metro Data). Real estate agents and developers reinstated the use of the name "Highlands"; developer Paul Tamburello, named by the *Denver Post* as "the godfather of rejuvenated Highlands" (Husted 2010) invented "LoHi," or Lower Highlands, to promote his LoHi Market Place. The neighborhood's name fast became a fault line between gentrifiers and long-time residents; one group made t-shirts that read, "You mean Northside? *¿Como que Highlands?*" (Mejia 2014).

Like Auraria, the Northside had high rates of Hispanic home ownership, due in large part to redlining (Figure 2). Yet with meat-cleaver urban

renewal out of fashion, the city's involvement in making the rent gap profitable had to take a different form. Langegger (2013, 2017) identifies one tactic by which this involuntary gentrification was achieved: the policing of public space, first to break down its use by Chicano community and political organizing, and later to "enshrine" the "middle-class norm of single-use neighborhoods," to "usurp Latino ideas of legitimate public practices" (Langegger 2017, 39).

A key anecdote to the gentrification of the Northside—recounted in Langegger (2013, 2017), told to me by neighborhood activists in my own fieldwork, and utilized on the campaign trail by Federico Peña, Denver's first Hispanic mayor—is that of La Raza Park. Highland's street grid includes an alphabet of Native American tribes, and there's a park on Navajo Street that was called Navajo Park. In 1971, the remaining Italian-Americans in the neighborhood (again, by then just six percent of residents) successfully petitioned the parks department to rename Navajo Park to Columbus Park, a seeming last clutch of territorialism in the midst of the Chicano Movement, in which Denver had become central.

In March of 1969, Denver's Crusade for Justice, helmed by boxer-turned-activist Rodolfo 'Corky' González, hosted 1500 Mexican-American youth from across the United States for the National Youth and Liberation Conference. That conference birthed the Plan Espiritual de Aztlán, the widespread use of the term "Chicano" and "Chicanismo," and the nationwide student organization MEChA (Simpson 2016). A central tenet of the Crusade for Justice's Chicanismo was that community institutions needed to be under community leadership (Vigil 1999), and one such institution that Northside community leaders felt should be run by the community was Navajo Park and its pool.

The summer after the park was re-christened Columbus Park, Northside residents staged a take-over, called a "splash-in." Neighborhood kids swarmed the pool all at once, without paying, to taunt the lifeguards—white teenagers from other neighborhoods—until they quit. The adults in the neighborhood had been training teenagers to be lifeguards, so that they could apply for the jobs. The community renamed the park La Raza Park, and used it to host swimming and diving teams, workshops, and other events, including the Chicano National Conference (Langegger 2013; Lopez n.d.). For eleven years, they held a "grand opening" party on the day of the first splash-in, attended by crowds of up to 1500 people (Figure 3).

Figure 3. 11th annual La Raza Park Grand Opening (*Viva Northside* Facebook group).

On June 28, 1981, at Grand Opening 11, Denver Police Department SWAT teams arrived with clubs, dogs, and tear gas (Langegger 2013; Lopez n.d.; see Figure 4). Within months after the raid, all the street parking surrounding the park had been replaced by "No Parking" signs; the following year, the pool was filled with concrete, and the "La Raza Park" signs were replaced with "Columbus Park."

Figure 4. Denver Police SWAT teams shut down the 11th Annual La Raza Park opening photos (*Viva Northside* Facebook group).

Langegger (2013) argues that this "heavy-handed policing along with profound changes to the design and programming of La Raza Park effectively dislodged the Crusade for Justice from North Denver," while Langegger (2017) argues that the same tactics

of double standards for urban regulations, differentiated access to public space, and racialized policing were used in the early 2000s to change public space "*in order to* change surrounding neighborhoods" (Langegger 2017, 40). When patrons of the restaurant Root Down, another project of Paul Tamburello, complained about the shortage of parking, the restaurant helped facilitate the transformation of all surrounding street parking into two-hour slots—meaning that residents could no longer park their cars there. In the park across the street, the parks department removed the goal posts, arguing that too much soccer playing was compacting the soil—only to replace it with a dog park.

Just as Auraria's urban renewal dispersed a tight-knit community, so the gentrification of the Northside has sent long-time residents in all directions. "People go to Green Valley Ranch [a new housing development near Denver International Airport], to the northern suburbs, some go as far as Greeley," Bobby Lefebre, a Northside community activist and the current poet laureate of Colorado. "They'll rebuild a community, but it will take a long time to come close to what they've lost" (Bobby Lefebre, interview with author, June 2016).

Globeville-Elyria-Swansea: Urban Renewal's Neoliberal Return

Denver's current displacement fight is taking place in the neighborhoods of Globeville and Elyria-Swansea (collectively "GES"). Until World War II, GES was populated by Eastern European immigrants, including German-Russians, Poles, Slovenians, and Serbo-Croatians. The neighborhoods were founded around smelters, and remain industrial today, with a still-functioning lamb slaughterhouse, a Purina factory, and other industry; the area's zip code, 80216, is considered the most polluted in the country (Svaldi 2017a).

Doeppers (1967) captures the cultural geography of Globeville at its moment of transition from immigrant European to Mexican-American. He writes, "Globeville is now in the second generation beyond the immigrant experience, and distinct departures from the past are taking place. As the old-line families move to the suburbs, a new group, the Mexican-Americans, is replacing them." Three "push" factors precipitated this shift: World War II veteran's loans to move to the suburbs; a housing project that brought low-income African-Americans and Mexican-Americans into the neighborhood; and, as in Highland, the construction of Interstate 70. "Thirty-one of the best kept homes in Globeville were demolished and replaced with a 'Chinese Wall' that literally separates friends and truncates the community…Globevillians feel that an impersonal bureaucracy ran roughshod over their desire to preserve the community" (Doeppers 1967, 514).

Ironically, that very disruption that enabled Hispanic residents to move into GES is now facilitating their displacement, and leaving them feeling runover roughshod. In late August 2014, the Colorado Department of Transportation released a plan to add four toll lanes to I-70 through Denver and to sink the two miles that pass through GES, at a cost of the condemnation of 56 homes and 17 businesses—more than the original construction consumed—in addition to the fields connected to Swansea Elementary School. It received approval from outgoing Transportation Secretary Anthony Foxx on January 19, 2017, the last day of the Obama administration (Tracey 2017).

The freeway project looks a lot like the type of mid-century urban renewal that scraped Auraria; in Denver and other cities, Interstates were common agents of racialized neighborhood demolition. However, as the country's political economy has changed toward the neoliberal, so has the execution of large-scale public works projects. HUD no longer offers funds for demolition of neighborhoods, and Colorado's infamous TABOR (Taxpayer's Bill of Rights) makes it nearly impossible for the state's government to directly spend money. Instead, public works projects are accomplished through Public-Private Partnerships, in which a private entity is charged with a public works project, and which do not require voter approval. At a 2019 public forum, incoming Colorado governor Jared Polis said, "P3s are the worst way to fund anything; but if they're the only way, what can you do?" (Keith Howard, interview with author, January 2020).

GES are the last "ungentrified" neighborhoods in the city center, but that is changing fast. Median property values rose 50% between 2017 and 2019 (Bryson 2020), after having risen 67% from 2015-2016 (Tracey 2016). Speculators are banking on gentrification spilling over from nearby Five Points, a historically African-American neighborhood that now has the highest rent in Denver (Svaldi 2017b) and RiNo (River North, a formerly industrial area now home to art galleries and artisanal food purveyors, whose development was also a project of

incumbent mayor Michael Hancock) districts; and that the redevelopment of Globeville's National Western Complex and I-70 will make GES increasingly attractive to development.

The city's auditor and planning director both resigned over the project (Dennis Gallagher, interview with author, May 2017; Rocky Piro, personal communication, December 2019), and the neighborhood mobilized, first with protests (see Figure 5) and later with legal action. A Civil Rights Act Title 6 Complaint with the U.S. Departments of Transportation and Justice and the Federal Highway Administration arguing that the project had a disproportionate impact on communities of color was dismissed with the response that the impact was not disproportionate "enough," despite affecting three of Denver's last greater-than-80 percent Hispanic neighborhoods; an environmental lawsuit against CDOT was settled with the outcome that the agency would install a few more monitoring stations for air pollution—"not really a win so much as a draw," according to community activist Brad Evans (interview with author, January 2020). The project is now underway.

Figure 5. Ditch the Ditch activists (https://www.westword.com/news/angry-protesters-challenge-cdots-so-sue-us-stance-on-i-70-expansion-8807165).

Conclusion

Historian Nathan Connolly writes that in the American city, "segregation itself becomes a kind of technology, one under constant innovation" (Connolly 2009). In Denver's twentieth century, race, and space have been under continuous re-innovation in the name of developer profits and the sustained expansion of white affluence. In particular, the city's Hispanic neighborhoods—centrally-located, rife with historic buildings, and long artificially devalued by redlining—have exemplified the different modes of city government-led displacement of each epoch of twentieth-century urban political economy.

Henri Lefebvre (2003 [1970]) writes that "Urbanism…blocks a view of the horizon, a path to urban knowledge and practice. It accompanies the decline of the spontaneous city and the historical urban core…[It is] an image of force and restraint." Amidst the staggering natural beauty of Denver, its charming interlocked grids of brick homes and street trees, its enchantingly sunny blue sky and seemingly endless relaxed friendliness, there is a challenge, then, for the visiting geographer: to see that force and restraint in the texture of the contemporary city, to observe how it works to our benefit, at the expense of others.

Notes

1. "Hispanic" and "Latinx" are imperfect umbrella terms for a complex assemblage of racial formations that are differently preferred according to geography and generation. The term "Hispanic" was created after the 1960 census as an alternative to the category "white"—which had been the historical preference of the Mexican-American elite (Molina 2014)—to describe anyone of Spanish and Spanish-speaking Latin American descent. Over time, it consolidated into an identity category, and became a preferred term for self-identification (Mora 2014). Latino/Latinx is a more recent term that refers to anyone of Spanish- or Portuguese-speaking Latin American descent. Many of the Southwest's historic Spanish-speaking communities refer to themselves as "Spanish," making Hispanic the more historically appropriate term. With increased immigration from countries besides Mexico, especially waves of immigration that took place after the rise of the term Latino, as well as new generations of activists, Latinx is becoming increasingly common. However, a Pew Research Center study showed that half the population has no preference between the terms (Pew 2013). I use Hispanic throughout this article, both because of the article's historic perspective and because the term remains in use by current activists. I use "Chicano" for political and community formations self-identified as such during the Chicano Movement of the 1970s.

2. Where these residents go? Many go to Adams County, to the north of Denver, which has the highest percentage of Hispanic/Latino residents of any county in metropolitan Denver: Adams County municipality Federal Heights, for instance, saw its Latino (as the census now designates) population grow from 31 to 62% between the years 2000 and 2017 (Denver Metro Data). The Latino populations of Aurora, Denver's largest suburb, and Weld County, in northern Colorado, have also grown considerably, as has the Latino population of historically black Montbello, and extreme northeast Denver's Green Valley Ranch (largely due to new construction).

References

Allen, T. 2019. Decades after the Auraria campus displaced a neighborhood, a scholarship meant to make amends may be on the last generation. *CPR News*, August 19. Accessed January 11, 2020 https://www.cpr.org/2019/08/19/decades-after-the-auraria-campus-displaced-a-neighborhood-a-scholarship-meant-to-make-amends-may-be-on-the-last-generation/.

Arellano, M. 2016. How can we see redlining's lasting impacts on Denver? *Denverite*, October 24. Accessed January 12, 2020. https://denverite.com/2016/10/24/can-see-redlinings-lasting-impacts-denver/.

Brooke, J. 1995. Court says Denver can end forced busing. *New York Times*, September 17. Accessed January 12, 2020. https://www.nytimes.com/1995/09/17/us/court-says-denver-can-end-forced-busing.html.

Brundin, J. 2013. 40 years since Keyes. *CPR News*, February 4. Accessed January 12, 2020. https://www. cpr.org/2013/02/04/40-years-since-keyes/.

Bryson, D. 2018. In the 60's, Denver decided to replace this community with the Auraria campus. Here's what it lost. *Denverite,* November 5. Accessed January 12, 2020. https://denverite.com/2018/11/05/denver-auraria-history-displacement/.

———. 2020. Median property value rose 50 percent in 2 years in Elyria-Swansea and Globeville—again. *Denverite*, January 8. Accessed January 11, 2020. https://denverite.com/2020/01/08/median-property-value-rose-50-percent-in-2-years-in-elyria-swansea-and-globeville-again/.

CdeBaca, C. 2017. Globeville, Elyria and Swansea could be erased without aggressive intervention. *Denver Post*, June 23. Accessed January 14, 2020. https://www.denverpost.com/2017/06/23/globeville-elyria-and-swansea-could-be-erased-without-aggressive-intervention.

Chase, G. T. 2011. Hispanic migration to northeastern Colorado during the nineteen twenties: Influences of sugar beet agriculture. MA thesis, University of Denver.

Clemmer-Smith, R. D., A. Gilbert, D. Fridtjof Halaas, B. Stratton, G. Tinker, and N. Wadsworth. 2014. *Report of the John Evans Study Committee, University of Denver*. Accessed January 12, 2020. https://www.du.edu/sites/g/files/lmucqz251/files/2018-04/DUJEC%20Report%20Nov12014.pdf.

Colorado Encyclopedia. 2016. Alamosa County. *Colorado Encyclopedia*. Accessed January 12, 2020. https://coloradoencyclopedia.org/article/alamosa-county.

Connolly, N. 2009. Timely innovations: plants, trains and the 'whites only' economy of a Pan-American city. *Urban History* 36 (2):243-61.

Denver Metro Data. 2020. Accessed January 13, 2020. https://denvermetrodata.org/map.

Denver Office of Economic Development. 2016. *Gentrification Study: Mitigating Involuntary Displacement.* Accessed January 12, 2020. https://www.denvergov.org/content/dam/denvergov/Portals/690/Reports%20and%20Studies/GENT%20STUDY%20051816.pdf.

Denver Public Library. n.d. Auraria Neighborhood History. Accessed January 11, 2020. https://history.denverlibrary.org/auraria-neighborhood.

Deutsch, S. 1987. *No separate refuge: Culture, class, and gender on an Anglo-Hispanic frontier in the American Southwest, 1880-1940.* Oxford: Oxford University Press.

Doeppers, D. F. 1967. The Globeville Neighborhood in Denver. *Geographical Review* 57 (4):506-522.

Evans, B. Interview by author. Denver, Colorado. January 7, 2020.

Fernández, J. E. 1976 [1911]. *Cuarenta años de legislador o biografía del Senador Casimiro Barela.* New York: Arno Press.

Garcia, A. 2010. *The pastoralcClinic: Addiction and dispossession along the Rio Grande*. Berkeley: University of California Press.

Gallagher, D. Interview by author. Denver, Colorado. May 15, 2017.

Goetz, A. R. and E. E. Boschmann. 2018. *Metropolitan Denver: Growth and change in the Mile High City (Metropolitan Portraits)*. Philadelphia: University of Pennsylvania Press.

Greenberg, M. 2017. Tenants under siege: Inside New York City's housing crisis. *New York Review of Books*, August 17. Accessed January 13, 2020. https://www.nybooks.com/articles/2017/08/17/tenants-under-siege-inside-new-york-city-housing-crisis/.

Howard, K. Interview by author. January 9, 2020.

Hunt, R. A. 1999. Urban pioneers: Continuity and change in the ethnic communities of two Denver, Colorado neighborhoods 1875-1998. PhD diss., University of Colorado Boulder.

Husted, B. 2010. Paul Tamburello is the father of rejuvenated Highland. *Denver Post*, November 3. Accessed January 13, 2020. https://www.denverpost.com/2010/11/03/paul-tamburello-is-the-father-of-rejuvenated-highland/.

Klinkenborg, V. 2000. The conscience of place: Sand Creek. *Mother Jones,* November. Accessed January 12, 2020. https://www.motherjones.com/politics/2000/11/conscience-place-sand-creek/.

Lamar, H. 2000 [1966]. *The Far Southwest, 1846-1912: A territorial history*. Albuquerque: University of New Mexico Press.

Langegger, S. 2013. Viva la raza! A park, a riot and neighbourhood change in North Denver. *Urban Studies* 1-18.

———. 2017. *Rights to public space: Law, culture, and gentrification in the American West*. Cham: Palgrave Macmillan.

Lefebre, B. Interview by author. Denver, Colorado. June 12, 2016.

Lefebvre, H. 2003 [1970]. *The urban revolution* (trans. R. Bononno). Minneapolis: University of Minnesota Press.

Lopez, F. n.d. Post to *Viva Northside!* Facebook group. Accessed October 3, 2017.

Lozano, R. 2018. *An American language: The history of Spanish in the United States*. Oakland: University of California Press.

MEChA [MSC] Metropolitan State College. 1979. National Chicano student conference (direct mail flyer). Accessed January 14, 2020. https://library.ucsd.edu/dc/object/bb61105585/_1.pdf.

Mejia, J. 2014. 'Como que Highlands?'. *La Voz Colorado*, August 6. Accessed January 10, 2020. http://www.lavozcolorado.com/detail.php?id=7674.

Molina, N. 2014. *How race is made in America.* Oakland: University of California Press.

Mora, G. C. *Making Hispanics: How activists, bureaucrats, and media constructed a new American*. Chicago: University of Chicago Press.

Nostrand, R. L. 1992. *The Hispano homeland*. Norman: University of Oklahoma Press.

Page, B. and E. Ross. 2017. Legacies of a contested campus: Urban renewal, community resistance, and the origins of gentrification in Denver. *Urban Geography* 38 (9):1293-1328.

Peña, Devon G. 1998. "*Los Animalitos:* Culture, ecology, and the politics of place in the Upper Rio Grande." In D. G. Peña, ed. *Chicano Culture, ecology, politics: Subversive kin*. Tucson: University of Arizona Press.

Pew Research Center. 2013. "Preference for the terms 'Hispanic' and 'Latino.'" Accessed February 21, 2020. https://www.pewresearch.org/hispanic/2013/10/22/three-fourths-of-hispanics-say-their-community-needs-a-leader/ph-hispanic-leader-10-2013-03-04/.

Piro, R. Personal communication. Denver, Colorado. December 22, 2020.

Richardson, J., B. Mitchell, and J. Franco. 2019. Shifting neighborhoods: Gentrification and cultural displacement in American cities. *National Community Reinvestment Coalition.* Accessed January 12, 2020. https://ncrc.org/gentrification/.

Sakas, M. E. 2017. Discriminatory lending that once stifled Denver neighborhoods now fuels gentrification. *Colorado Public Radio*, October 10. Accessed January 12, 2020. https://www.cpr.org/show-segment/discriminatory-lending-that-once-stifled-denver-neighborhoods-now-fuels-gentrification/.

Simpson, K. 2016. Defining 'Chicanismo' since the 1969 Denver Youth Conference. *KCET*, March 24. Accessed January 12, 2020. https://www.kcet.org/history-society/defining-chicanismo-since-the-1969-denver-youth-conference.

Scott, A., A. Blanco and J. Reed. 2019. Decades after redlining, Denver schools see choice contributing to racial imbalance. *Colorado Sun,* February 5. 2019. Accessed January 12, 2020. https://coloradosun.com/2019/02/05/decades-after-redlining-denver-schools-see-choice-contributing-to-racial-imbalance/.

Smith, N. 1987. Gentrification and the rent gap. *Annals of the Association of American Geographers* 77 (3):462-465.

Standish, S. 2002. Beet borderland: Hispanic workers, the sugar beet, and the making of a northern Colorado landscape. MA Thesis, Colorado State University.

Svaldi, A. 2017a. Northeast Denver neighborhood is nation's most polluted. *Denver Post*, February 16. Accessed January 13, 2020. http://www.denverpost.com/2017/02/16/denver-most-polluted-zip-code.

———. 2017b. Five points has the highest rent in Denver, but Highlands Ranch has highest average rent in region. *Denver Post*, April 3. Accessed January 14, 2020. https://www.denverpost.com/2017/04/03/five-points-highlands-ranch-highest-rents-in-colorado/.

Tracey, C. 2016. White privilege and gentrification in Denver, 'America's favourite city.'" The *Guardian*, July 14. Accessed January 13, 2020. https://www.theguardian.com/cities/2016/jul/14/white-privilege-gentrification-denver-america-favourite-city.

———. 2017. Redlining returns to Denver, but with a neoliberal twist. *The Nation*, July 31. Accessed January 13, 2020. https://www.thenation.com/article/redlining-returns-to-denver-but-with-a-neoliberal-twist/.

University of Colorado Denver. 2020. Displaced Aurarian Scholarships. Accessed January 12, 2020. http://www.ucdenver.edu/student-services/resources/CostsAndFinancing/FASO/Learn/FAQs/Types/Scholarships/Pages/Displaced-Aurarian-Scholarship.aspx.

Vigil, E. 1999. *The crusade for justice: Chicano militancy and the government's war on dissent*. Madison: University of Wisconsin Press.

Wiberg, R. E. 1976. *Rediscovering Northwest Denver: Its history, its people, its landmarks*. Denver: Northwest Denver Books.

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A CARTOGRAPHIC EXPLORATION OF THE GEOGRAPHIES OF OBESITY IN DENVER

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Introduction

The Centers for Disease Control (CDC) (2019) define overweight and obesity as "weight that is higher than what is considered as a healthy weight for a given height." BMI is the most common height-standardized operational definition of overweight and obesity, calculated from individual's weight in kilograms divided by the square of their height in meters. Adults are classified as overweight if their BMI is between 25 and 30, and obese if their BMI is 30 or greater. The World Health Organization has observed more than a three-fold increase in global obesity rates since 1975 and major public health organizations have begun to recognize obesity "as one of the most serious public health challenges in the 21st century" (World Health Organization 2019). The CDC estimate that in 2015-2016, the overall crude prevalence of obesity was 39.8% among adults and 18.5% among youth in the U.S. (Hales et al. 2017). This rise in obesity has major implications for the future health of entire populations and is frequently referred to as a "global pandemic" (e.g., Afshin et al. 2017). Obesity is associated with increased risk for various types of cancer, type 2 diabetes, hypertension, cardiovascular disorders, among other health problems (Poirier et al. 2006).

Research in geography and other disciplines has shown that the physical, social, and economic variation among communities and neighborhoods affects health (Diez Roux 2001). There is ample evidence of a clear association between high body mass index (BMI) rates and local-scale area disadvantages (Pearce and Witten 2010, Murphy et al. 2017, Schwartz et al. 2011) due to a complex interaction of geographic and contextual factors which include the social, cultural, economic and built environments. The notion that the built environment is a factor in the obesity epidemic is appealing for the general public, public health advocates, and policymakers, because it suggests that the problem can be addressed by improving environmental conditions. A tangible and intuitive path for addressing the problem is through the creation of leptogenic environments (the term "leptogenic" is borrowed from medical literature and means "encouraging slimness") that encourage physical activity and healthy diet through careful planning. Efforts to build accessible, safe green spaces and walking paths, for example, could prompt residents to engage in more physical activity. Similarly, policies that encourage a variety of spatially accessible and affordable food options such as green grocers could encourage healthy eating.

Scholarship on the role of the built environment in the obesity epidemic has yielded mixed results, however, and it is unclear which factors are the key drivers (Pearce and Witten 2010, Leung et al. 2011, Lebel et al. 2012, Johnson et al. 2019). Three well explored links between environmental risk factors and high BMI include the socio-economic environment, walkability, and access to healthy foods. Policymakers have ultimately struggled to identify any clear solution for addressing the obesity epidemic due to its complex nature and the need to address it at varying geographic scales from local communities to the national level (Swinburn et al. 2011).

A major barrier in efforts to understand the environmental facets of obesity epidemic is a paucity of reliable, high-resolution spatial (i.e., geographic) data on body mass index (BMI). While there are ample examples of spatially referenced health surveillance systems that monitor disease and risk environments such as air pollution, infectious disease, and cancer, few systems are in place to assemble geographically referenced data on BMI. The primary effort in the United States is the Behavioral Risk Factor Surveillance System (BRFSS), which reports obesity rates for adults aggregated by county (see CDC 2016). Because the BRFSS only utilizes self-reported data aggregated into counties, it is not useful for evaluating patterns within cities and across neighborhoods. Most scholarly work exploring links between obesity and the built environment relies on small sample sizes or self-reported data, which

imposes serious limitations on the generalizability of the work (Barbosa et al. 2019).

With funding from the Colorado Health Foundation, several local health care providers collaborated with the University of Colorado and the Colorado Department of Public Health and Environment (CDPHE) in 2013 to build the Colorado BMI Monitoring System, a high-resolution monitoring system for Denver and the surrounding communities (see Anthamatten et al. 2020). Participating health care providers from Denver region included Children's Hospital Colorado, Denver Health, Kaiser Permanente, the Metro Community Provider Network, and Salúd Family Health Centers.

Each of the five participating clinical systems collected patient data from routine clinical visits, including the patient's height, weight, age, race/ethnicity, and physical address. After each provider cleaned the data (such as removing obvious data entry errors) and removed information that could be used to identify individuals, they were sent to the Colorado Department of Public Health and Environment (CDPHE). Participating providers and the CDPHE geocoded patient addresses—a process for transforming residential addresses into latitude/longitude coordinates—to enable mapping. Drawing from the patient information in the system and population data from the U.S. Census Bureau, the CDPHE produced maps of obesity by census tract for the seven-county Denver metropolitan area, available on their website for public use (CDPHE 2019). The initial phase of the project included patient data from 2013 to 2015, and it has since been updated to show data from 2014 to 2016. The purpose of this essay is to provide a cartographic exploration of these data to explore patterns in obesity across the city of Denver. I have also produced maps of some of the suspected environmental factors to illuminate related patterns in the city's socioeconomic, physical activity, and food environments.

Using the Colorado BMI Monitoring System to Explore Spatial Patterns of Obesity in Denver

The Colorado BMI Monitoring System includes both maps and tabular data of estimates of obesity and overweight by census tract and statistical neighborhoods, with separate data for children (patients between two and seventeen years old) and adults. Rates for overweight and obesity were calculated by dividing the number of individuals considered overweight or obese by the total number of individuals with height and weight data. Each adult was considered obese if their BMI was greater than 30. Children were classified as obese using the CDC growth charts if their weight was higher than the 95th percentile (Pi-Sunyer et al. 1998).

While the project organizers sought to provide an important health monitoring tool for the public, it was also important to protect individual privacy and avoid sharing figures with a low degree of certainty. BMI rates were not reported for census tracts or neighborhoods with fewer than 50 residents, fewer than 50 valid BMI measurements, or with a low portion of the total census tract population (defined as having BMI data on 10% or less of the total neighborhood population for adults and 20% or less for children). Finally, because age is associated with BMI, the CDPHE also provides age-adjusted estimates for adult rates. Age-adjusted rates enable comparison across populations with different age structures by applying age-specific rates to a standard population structure.

Among the products available from the Colorado BMI Monitoring System are data and maps aggregated by neighborhoods, census-defined collections of tracts intended to represent urban communities, more meaningful for residents and policymakers than census tracts. I have included a basic reference map of the city and county of Denver that shows the neighborhoods included in the monitoring system, along with the major interstate highways (Figure 1).

The BMI monitoring system includes nearly complete coverage of adult obesity rates at the neighborhood scale of aggregation, missing data from only a small number of neighborhoods near the Central Business District (CBD). The age-adjusted neighborhood obesity rates for adults range from 11.6% to 42.9% (Figure 2). While these rates are generally much lower than the national rate in the U.S. (39.8%), there is clear spatial variation across the city. Notably, low rates of under 20% characterize the central and southern central parts of the city, while rates in the western part of the city, just west of Interstate 25, and in the north central neighborhoods around Interstate 70, are above 35%.

Obesity rates for children (Figure 3) are much lower than adults, ranging from 2.1% to 22.8% by neighborhood across the city, also generally much lower than the national average for childhood obesity (18.5%). This work supports research in the past that observes low rates in Colorado and other western states (e.g., Tudor-Locke et al. 2007) relative to other parts of the United States. Unsurprisingly, the

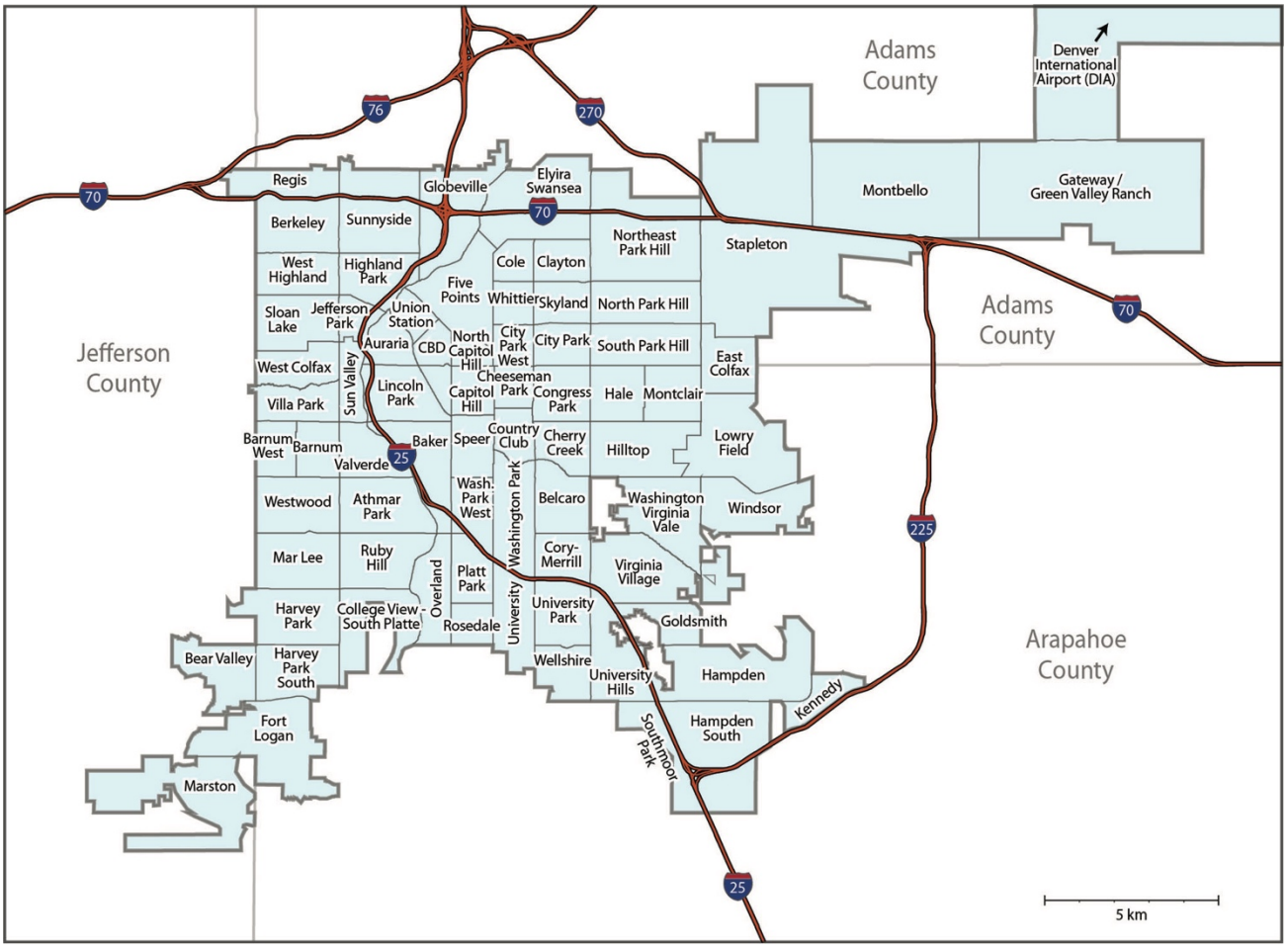

Figure 1. Neighborhoods of Denver, Colorado. Data were derived from the City and County of Denver (2020).

patterns across the city are strikingly similar to the adult rates, with the highest figures in neighborhoods in the northern and western parts of the city.

There is evidence that neighborhood poverty is associated with higher BMI. Children may be particularly vulnerable; Alvarado (2019) employed a fixed-effects model to separate the influences of exposure to low-income neighborhoods to discover that the BMI of adolescents (aged 13-18) and young adults (aged 19-30) were strongly influenced by living in a low-wealth neighborhood. Despite some serious problems separating the effects of living in a low-income neighborhood from confounding variables, there is broad consensus that poverty is associated with higher rates of obesity in the U.S. and most other industrialized settings.

Readers familiar with the social geography of Denver may recognize that patterns of obesity rates

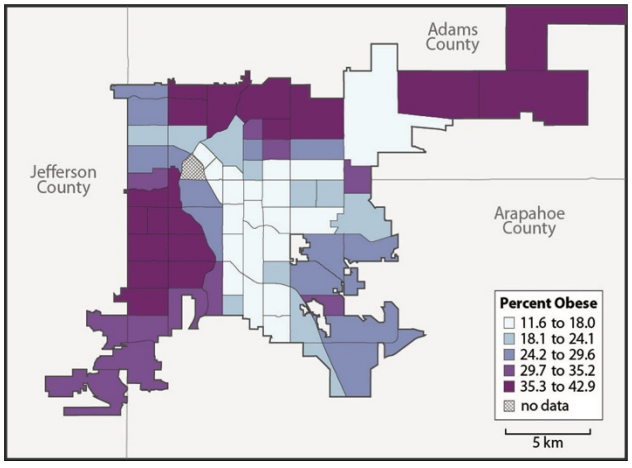

Figure 2. Age-adjusted obesity rates for adults by neighborhood in the city of Denver, categorized into quintiles. Data are from the BMI Monitoring System (Colorado Department of Public Health and Environment 2019).

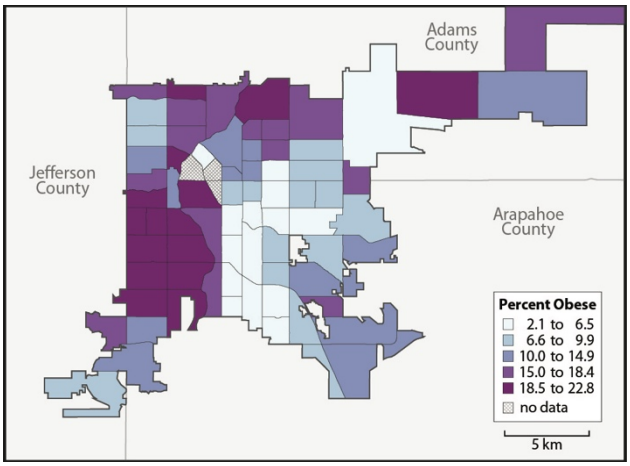

Figure 3. Obesity rates for children and youth (aged 2 to 17) by neighborhood in the city of Denver (divided into quintiles). Data are from the BMI Monitoring System (Colorado Department of Public Health and Environment 2019).

align closely with wealth (Figure 4). The wealthiest areas in the central part of the city—such as Cherry Creek, Country Club, and Belcaro neighborhoods—have the lowest obesity rates, while the neighborhoods with the lowest income, encompassing largely Latino communities west of Interstate 25, have the highest rates. The map of neighborhood income appears to be a close inverse of the obesity maps—the lowest income neighborhoods have the highest obesity rates and vice versa.

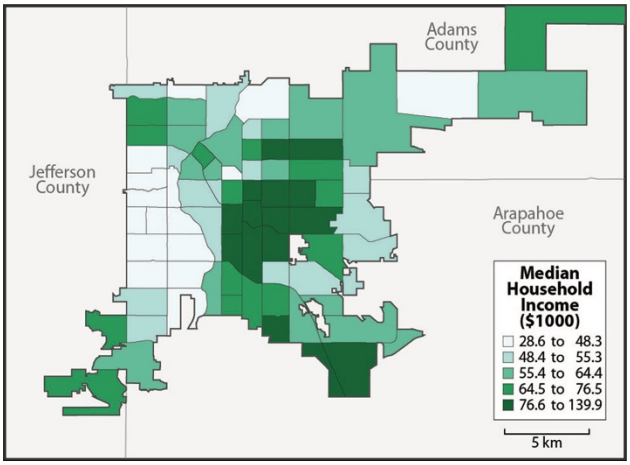

Figure 4. Median household income by neighborhood in Denver (in quintiles). Income figures were derived from the American Community Survey (United States Census 2018). I estimated neighborhood values by averaging data from the constituent census tracts.

The association between income and obesity rates, while expected, raises some important questions that scholars and policymakers continue to struggle with. What is it about low-income neighborhoods that makes them obesogenic—prone to encourage high BMI among its residents? While poverty seems to be at the root of many health disparities, it offers few practical solutions for addressing them. Is this association due to power structures and cultural geographies surrounding low-income communities in the U.S., or can we identify specific facets of the built environment that could be addressed through policy?

The role of "physical activity environment" has received significant attention as a potential factor driving these patterns. The idea is that neighborhoods with good access to safe and appealing opportunities for walking—with nearby parks, green spaces, and local economic opportunities—improves the likelihood that residents engage in regular physical activity (Colley et al. 2019), ultimately posing a lower risk for obesity than less "walkable" neighborhoods (Stowe et al. 2019, Tarlov et al. 2019). Providing an objective measure of walkability is complex because it pertains to multiple factors including residential density, land use mix, street intersection density, sidewalk quality, access to public transit, and crime (Huang et al. 2020, Cain et al. 2014, Creatore et al. 2016).

Fortunately, the Environmental Protection Agency (EPA) provides high-quality data on walkability. The EPA funded a meta-analysis to determine which built environment variables were associated with residents' travel behavior (Ewing and Cervero 2010). Drawing from this work, they derived the National Walkability Index, which rates the walkability of census tracts with a weighted formula that takes several built environment factors into account (EPA 2019).

Figure 5 is a map of the EPA's walkability index of Denver's neighborhoods. The areas with the highest scores are the densely populated, central portions of the city near the Central Business District and the Auraria Campus, as well as the wealthiest neighborhoods in the south-central part of the city. Areas on the extremities of the city have the lowest walkability scores, loosely reflecting the patterns on the maps of obesity rates and resident median household income.

Stimulated in part by a discussion around a "food poverty" bill in the UK (see Cummins and Macintyre

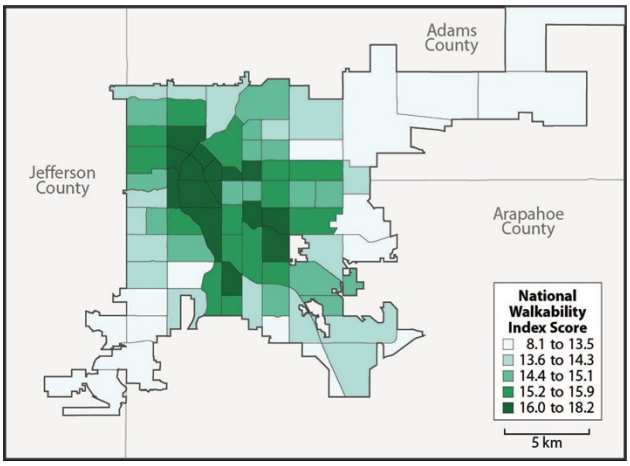

Figure 5. The National Walkability Index score by neighborhood (Environmental Projection Agency 2019). While the specific values have little intrinsic meaning, they provide a good overview for comparison and mapping. Data are divided into quintiles.

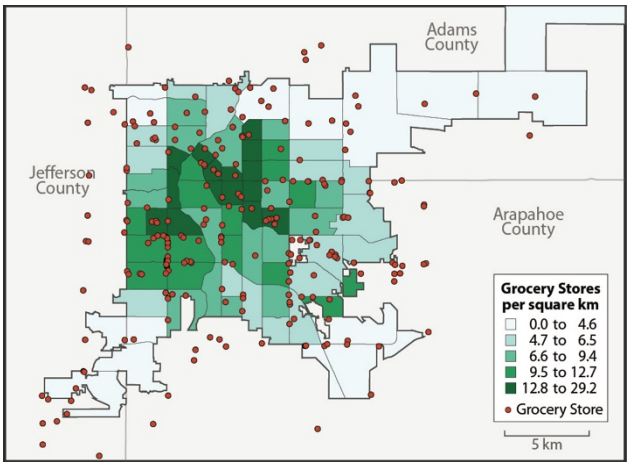

Figure 6. A map of grocery stores and grocery store density by neighborhood in Denver (Data source: City and County of Denver 2020). Figures were calculated by calculating the aerial density of the number of grocery stores, superstores with food (e.g., Target), and specialty food stores within a one kilometer buffer of each neighborhood.

2002), a massive body of literature has emerged over the last fifteen years to examine the effects of the built environment on energy consumption through the study of "food deserts," neighborhood environments where there is poor economic and spatial access to healthy food. The concept of food deserts often pertains to low-income neighborhoods where nearly all affordable and available food constitutes high-calorie options with low nutritional value, such as food found in many fast-food restaurants and convenience stores.

The modern food environment is highly place-dependent and complex, driven by individuals' spatial, economic, as well as cultural access to healthy food options. While a rigorous study of the food environment involves careful data collection and modelling, publicly available data enable a rough overview of spatial patterns of food access within the city. Included among data open to the public from the City and County of Denver (2019) are spatial data food access points. The data include up-to-date locations of various types of grocers, convenience stores, pharmacies, and restaurants. Figure 6 shows the average density of "healthy" types of food stores (grocery stores, superstores, and specialty grocers) for areas within one kilometer (0.62 mile) of each neighborhood.

This map does not bear as strong resemblance to the maps of obesity rates as the others. The western corridor of the city along I-25 shows a high food store density, similar to the areas around the Central Business District. The extremities of the city, notably the northern corridor along Interstate 70, have much lower food densities.

While income, walkability, and food access presumably bear some relation to BMI, each is a generally positive facet of a thriving, healthy urban environment. The final map shows a simple index of these three variables (Figure 7). The map was derived by adding the quintiles (the least favorable quintile was assigned a value of one, the next highest a two, etc.) from income, walkability, and food store density. This map is intended provide a rough overview of spatial patterns in the built urban environment that incorporates the environmental indicators explored in this essay. The low values on the map (with a score between 3 and 7) indicate the neighborhoods that rank the lowest in all three measures, while the highest values (12 to 15) show the parts of the city that consistently rank high.

The map reveals a striking pattern: The center of the city yields the most positive scores (suggesting a healthy built environment) surrounded by a ring of middling values, with the lowest scores occurring at the fringes of the city. This pattern is a clear indication of inequalities in the neighborhood environments across the city.

An Overview of Obesogeneity in Denver's Built Environment

This cartographic overview of the geographies of obesity in Denver's urban environment provides a

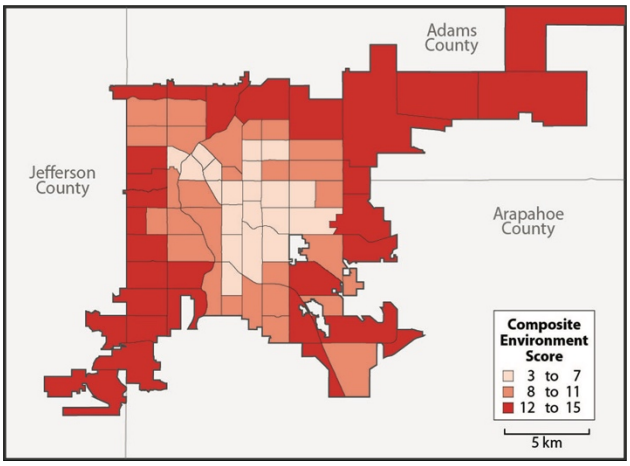

Figure 7. This map was produced by adding the quintiles for each neighborhood for each of the three environmental variables examined in this essay: median household income (data from the United States Census 2018), walkability score (Evironmental Projection Agency 2019), and food store density (City and County of Denver 2019).

cursory examination of possible drivers to spatial variation in BMI across the city. There are, however, clearly visible and related spatial associations. The obesity rates and each of the covariates examined in this essay (median household income, walkability score, and food store density) have reasonably normal distributions, enabling a least squares ordinary regression. The output of the statistical work is included in Table 1 for readers with familiarity with such statistical techniques.

Median household income and walkability had a statistically significant negative association with both child and adult obesity (β = -$291 for adults; β = -$202 for children). Intriguingly, there was a statistically significant negative association between neighborhood walkability scores for adults (β = -2.2), but not for children, perhaps suggesting that walkability is more relevant for adults' health than children's. There was no statistically detectable relation between obesity rates and food store density for either adults or children.

While it is well beyond the purview and scope of this paper to perform a rigorous quantitative analysis enabling statements about causality, this mapping exercise indicates some consistent patterns in the city, which could serve as a call to perform analysis using the high quality data provided by the Colorado BMI Monitoring system. Neighborhood income levels and walkability are clearly associated with obesity rates, while there is no clear relation between food store density and obesity. There are clear disparities in the city, suggesting that as the city continues to grow, more attention should be given to improving the built environment around the fringes of the city, where the basic indicators of a healthy environment examined here appear to be relatively poor.

The availability of longitudinal, high-quality, high-resolution data on body mass index presents an opportunity for researchers to explore relations between local urban environments and obesity rates.

Table 1. Simple Ordinary Least Squared Linear Models of Neighborhood Obesity with Income, Walkability, and Food Store Density in Denver, Colorado.

Variable	Adults		Children and Youth	
	slope estimate	p-value	slope estimate	p-value
Median Household Income *(thousands of dollars)*	-0.29	<0.01	-0.20	<0.01
Walkability Score	-2.25	<0.01	-0.56	0.16
Food Store Density *(stores per square km)*	-0.02	0.86	0.08	0.24

As the system continues to yield more data into the future, it will present an opportunity for planners and policymakers to evaluate the impacts of local interventions—such as local health education campaigns, construction projects, and planning decisions—on the obesity epidemic. A description of the construction of the monitoring system has been published (Anthamatten et al. 2020) and quantitative analysis of patterns in the data led by other members of the team is currently underway.

References

Afshin, A., M. H. Forouzanfar, M. B. Reitsma, P. Sur, K. Estep, A. Lee, L. Marczak, A. H. Mokdad, M. Moradi-Lakeh, M. Naghavi, et al. 2017. Health effects of overweight and obesity in 195 countries over 25 years. *New England Journal of Medicine* 377 (1):13-27. doi:10.1056/NEJMoa1614362.

Alvarado, S. E. 2019. The indelible weight of place: Childhood neighborhood disadvantage, timing of exposure, and obesity across adulthood. *Health & Place* 58:11. doi:10.1016/j.healthplace.2019.102159.

Anthamatten, P., D. Thomas, D. Williford, J. Barrow, K. Bol, A. Davidson, S. Deakyne-Davis, E. McCormick, D. Tabano, and M. Daley. 2020. Geospatial monitoring of body mass index: Use of electronic health record data across health care systems. *Public Health Reports* 135 (2):211-219. doi:10.1177/ 0033354920904078.

Barbosa, J.P.d.A.S., P. H. Guerra, C.d.O. Santos, A.P.d.O.B. Nunes, G. Turrell, and A. A. Florindo. 2019. Walkability, overweight, and obesity in adults: A systematic review of observational studies. *International Journal of Environmental Research and Public Health* 16 (17):17. doi: 10.3390/ijerph16173135.

Cain, K. L., R. A. Millstein, J. F. Sallis, T. L. Conway, K. A. Gavand, L. D. Frank, B. E. Saelens, C. M. Geremia, J. Chapman, M. A. Adams, K. Glanz, and A. C. King. 2014. Contribution of streetscape audits to explanation of physical activity in four age groups based on the microscale audit of pedestrian streetscapes (maps). *Social Science & Medicine* 116:82-92. doi:10.1016/j.socscimed.2014.06.042.

[CDC] Centers for Disease Control and Prevention. 2019. Defining adult overweight and obesity. Accessed February 5, 2020. https://www.cdc.gov/obesity/adult/defining.html.

———. 2016. Adult obesity prevalence maps. Last Modified August 31, 2017, Accessed August 16, 2019. https://www.cdc.gov/obesity/data/prevalence-maps.html.

Colorado Department of Public Health and Environment. 2019. Colorado BMI Monitoring System. Accessed December 19, 2019. https://www.cohealthmaps.dphe.state.co.us/colorado_bmi_monitoring_system/.

City and County of Denver. 2020. Open Data Catalog. Accessed January 3, 2020. https:// www.denvergov.org/opendata.

Colley, R. C., T. Christidis, I. Michaud, M. Tjepkema, and N. A. Ross. 2019. The association between walkable neighbourhoods and physical activity across the lifespan. *Health Reports* 30 (9):3-13. doi:10.25318/82-003-x201900900001-eng.

Creatore, M. I., R. H. Glazier, R. Moineddin, G. S. Fazli, A. Johns, P. Gozdyra, F. I. Matheson, V. Kaufman-Shriqui, L. C. Rosella, D. G. Manuel, and G. L. Booth. 2016. Association of neighborhood walkability with change in overweight, obesity, and diabetes. *JAMA-Journal of the American Medical Association* 315 (20):2211-2220. doi:10.1001/jama.2016.5898.

Cummins, S., and S. Macintyre. 2002. "Food deserts"—evidence and assumption in health policy making. *BMJ (Clinical research ed.)* 325 (7361):436-438. doi:10.1136/bmj.325.7361.436.

Diez Roux, A. V. 2001. Investigating neighborhood and area effects on health. *American Journal of Public Health* 91 (11):1783-9. doi:10.2105/ ajph.91.11.1783.

[EPA] Environmental Projection Agency. 2019. Smart location mapping: Interactive maps and data for measuring location efficiency and the built environment. Accessed December 21, 2019. https://www.epa.gov/smartgrowth/smart-location-mapping#walkability.

Ewing, R., and R. Cervero. 2010. Travel and the built environment. *Journal of the American Planning Association* 76 (3):265-294. doi:10.1080/01944361003766766.

Hales, C. M., M. D. Carroll, C. D. Fryar, and C. L. Ogden. 2017. Prevalence of obesity among adults and youth: United States, 2015-2016. *NCHS Data Brief* (288):1-8. https://www.cdc.gov/nchs/data/databriefs/db288.pdf.

Huang, J. H., J. A. Hipp, O. Marquet, C. Alberico, D. Fry, E. Mazak, G. S. Lovasi, W. R. Robinson, and

M. F. Floyd. 2020. Neighborhood characteristics associated with park use and park-based physical activity among children in low-income diverse neighborhoods in New York City. *Preventive Medicine* 131:12. doi:10.1016/j.ypmed.2019.105948.

Johnson, K. A., N. N. Showell, S. Flessa, M. Janssen, N. Reid, L. J. Cheskin, and R. L. J. Thornton. 2019. Do Neighborhoods matter? A systematic review of modifiable risk factors for obesity among low socio-economic status black and hispanic children. *Childhood Obesity* 15 (2):71-86. doi:10.1089/chi.2018.0044.

Lebel, A., Y. Kestens, R. Pampalon, M. Theriault, M. Daniel, and S. V. Subramanian. 2012. Local context influence, activity space, and foodscape exposure in two Canadian metropolitan settings: Is daily mobility exposure associated with overweight? *Journal of Obesity* 2012:912645. doi:10.1155/2012/912645.

Leung, C.W., B.A. Laraia, M. Kelly, D. Nickleach, N.E. Adler, L.H. Kushi, and I.H. Yen. 2011. The influence of neighborhood food stores on change in young girls' body mass index. *American Journal of Preventive Medicine* 41 (1):43-51. doi:10.1016/j.amepre.2011.03.013.

Murphy, M., M. J. Koohsari, H. Badland, and B. Giles-Corti. 2017. Supermarket access, transport mode and BMI: The potential for urban design and planning policy across socio-economic areas. *Public Health Nutrition* 20 (18):3304-3315. doi:10.1017/s1368980017002336.

Pearce, J., and K. Witten. 2010. *Geographies of obesity: Environmental understandings of the obesity epidemic*. Farnham, Surrey; Burlington, VT: Ashgate.

Pi-Sunyer, F. X., D. M. Becker, C. Bouchard, R. A. Carleton, G. A. Colditz, W. H. Dietz, J. P. Foreyt, R. J. Garrison, S. M. Grundy, B. C. Hansen, et al. 1998. Clinical guidelines on the identification, evaluation, and treatment of overweight and obesity in adults: Executive summary. *American Journal of Clinical Nutrition* 68 (4):899-917. https://www.ncbi.nlm.nih.gov/books/NBK2003/.

Poirier, P., T. D. Giles, G. A. Bray, Y. L. Hong, J. S. Stern, F. X. Pi-Sunyer, and R. H. Eckel. 2006. Obesity and cardiovascular disease: Pathophysiology, evaluation, and effect of weight loss—An update of the 1997 American Heart Association Scientific Statement on obesity and heart disease from the Obesity Committee of the Council on Nutrition, Physical Activity, and Metabolism. *Circulation* 113 (6):898-918. doi:10.1161/circulationaha.106.171016.

Schwartz, B. S., W. F. Stewart, S. Godby, J. Pollak, J. DeWalle, S. Larson, D. G. Mercer, and T. A. Glass. 2011. Body mass index and the built and social environments in children and adolescents using electronic health records. *American Journal of Preventive Medicine* 41 (4):E17-E28. doi:10.1016/j.amepre.2011.06.038.

Stowe, E. W., S. M. Hughey, S. H. Hallum, and A. T. Kaczynski. 2019. Associations between walkability and youth obesity: Differences by urbanicity. *Childhood Obesity* 15 (8):555-559. doi:10.1089/chi.2019.0063.

Swinburn, B. A., G. Sacks, K. D. Hall, K. McPherson, D. T. Finegood, M. L. Moodie, and S. L. Gortmaker. 2011. The global obesity pandemic: Shaped by global drivers and local environments. *Lancet* 378 (9793): 804-814. doi:10.1016/S0140-6736(11)60813-1.

Tarlov, E., A. Silva, C. Wing, S. Slater, S. A. Matthews, K. K. Jones, and S. N. Zenk. 2019. Neighborhood walkability and BMI change: A national study of veterans in large urban areas. *Obesity*: 9. doi:10.1002/oby.22611.

Tudor-Locke, C., J. J. Kronenfeld, S. S. Kim, M. Benin, and M. Kuby. 2007. A geographical comparison of prevalence of overweight school-aged children: The National Survey of Children's Health 2003. *Pediatrics* 120 (4):e1043-E1050. doi:10.1542/peds.2007-0089.

United States Census. 2018. "American Factfinder." Last Modified October 14, 2018. Accessed January 4, 2020. https://factfinder.census.gov/faces/nav/jsf/pages/index.xhtml.

World Health Organization. 2019. "Childhood overweight and obesity." Accessed November 21, 2019. https://www.who.int/dietphysicalactivity/childhood/en/.

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DENVER'S HISTORIC STREETCAR NETWORK AND ITS LEGACY OF WALKABLE NEIGHBORHOOD COMMERCIAL CORRIDORS

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Introduction: Trends in Urban Development, Transportation, and New Urbanism

In recent decades, many historic central city downtowns and neighborhoods have experienced a resurgence. Once declining, these places are now in such demand that affordability and gentrification have become major concerns. The City and County of Denver is no exception. In the past ten years its population has increased by 20% (Murray 2019) while median home prices have moved from approximately $250k to $450k. Price per square foot is 40% greater than in the suburbs (Zillow 2020).

The Congress for New Urbanism [CNU] sees this return to the city movement as a positive when compared to the prior status quo of urban abandonment and suburban expansion. Since the 1980's the CNU has advocated for the traditional form of city building that has been practiced for centuries, namely, "walkable blocks and streets, housing and shopping in close proximity, and accessible public spaces" (CNU 2020). Relative to the rest of metropolitan area, central Denver's built environment is most in line with this philosophy. This is due to a large population that existed at the time when walking and rail transit were the primary means of intraurban travel.

What characterizes this traditional form of city building, and how did we come to depart from it? For much of the entire history of human civilization, cities were walking cities and developed as such. Although variations existed, typically blocks were small, buildings were packed together, and businesses mixed in throughout (Morris 2013), such as the historic cores of many well-preserved European cities (Figure 1).

Beginning in the mid-19th century, the urban development pattern evolved around a new innovation: transit. Streetcars increased the speed at which people could travel and this in turn allowed them to live further from the urban core. Cities began growing on a grid system radiating out from the center, land became more segregated, and the density of buildings became less intense compared to walking cities of similar population. Despite the city's larger footprint, these streetcar suburbs remained internally accessible by foot and well connected by transit, with most residences having easy access to shops and services (Robertson and Cafky 1999, 2004; Muller 2017).

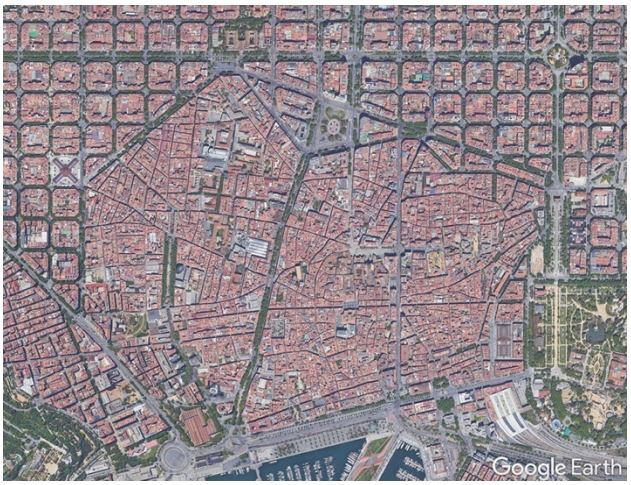

Figure 1. The oldest part of Barcelona, Spain contrasts clearly with the newer grid street pattern (Google Earth).

Under the influence of the automobile, the way cities were built in the United States underwent a more substantive change in the middle of the 20th century. Highways connected the center of town to the countryside, enabling high travel speeds and opening up more distant land to development. The central business district and older neighborhoods languished in favor of sprawling office parks, winding subdivisions, and large shopping malls on the edge of town (Figure 2). Driving became the way in which most of this new built environment was accessed, as it is too spread out and disconnected to access on foot or efficiently serve by transit. Many historic central cities eventually experienced mass abandonment and large scale demolition under urban renewal regimes (Figure 3) (Muller 2017).

New automobile centric development continues apace today. But as the ideals of the New Urbanism

Figure 2. Suburban Highlands Ranch development in southern metropolitan Denver (Google Earth).

movement has taken hold, some downtowns and inner-city neighborhoods are desirable once more, experiencing growth in both population and affluence (CNU 2020; Fishman 2008) as new residents seek many traditional neighborhood characteristics. For example, research has shown that neighborhood walk-ability—a key feature of historic streetcar neighbor-hoods—does increase housing values (Gilderbloom, Riggs, and Meares 2015; Redfin 2016). Similarly, many new subdivisions try to emulate these characteristics. The Stapleton neighborhood in Denver is a prominent example, whereby houses feature alleys and front porches instead of driveways and garage-scapes.

Figure 3. Downtown Denver in 1976, post urban renewal. Photo by Nick DeWolf.

The rest of this chapter is based on an Esri Story Map project that explores the evolution of Denver's historic streetcar neighborhoods, the land use around old streetcar lines, and how they influence walkability (Keeney 2017). The Story Map project is viewable at bit.ly/DenverStreetcarLegacy[1]. Using the textual narratives of Robertson and Cafky (1999, 2004), the entire streetcar network of Denver was digitized into the Story Map GIS environment, with details on each streetcar route, their dates of operation, and mode of propulsion. Before the completion of this project, no comprehensive map of Denver's streetcar system existed nor did a catalogue of Denver's historic commercial districts. The next section recounts the history of the evolution of Denver's streetcars from 1872 to 1950, followed by a section on the contemporary analysis of the legacy commercial corridors and walkability.

Denver's Streetcars: 1872-1950

Founded as a mining settlement in 1858, Denver began at the tail end of the walking era of U.S. cities. In 1872, after the town had grown to a population of about 4,700 people, the Denver Horse Railroad Company built the first public transit line in Denver. It consisted of a horse-drawn rail carriage (Figure 4) going from Auraria to Curtis Park through downtown (Robertson and Cafky 1999, 2004).

Figure 4. A horsecar (Denver Public Library, Western History Collection, [X-27856]).

By 1880 the trackage had expanded modestly (Figure 5), perhaps doubling in total length, radiating about 2.5 km out of the central business district. The population however, had ballooned seven-fold to 35,000. News reports at the time lamented the inadequate state of the network. In the face of pent-up demand and continued population growth, the 1880s saw the biggest single-decade expansion of the network in its 78-year history (Robertson and Cafky 1999, 2004).

By 1890, when the population tripled to 106,000, nearly every block in downtown and the Five Points

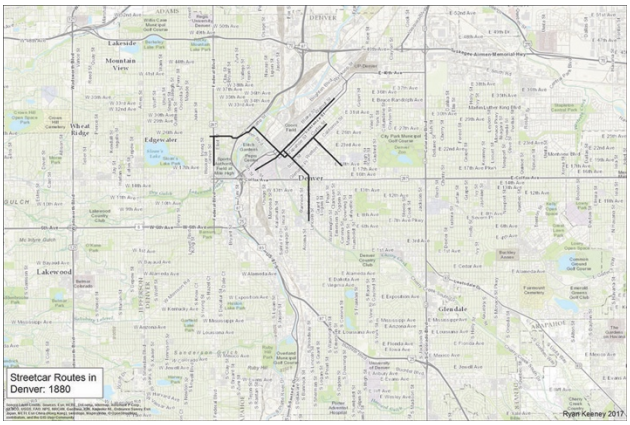

Figure 5. Denver's streetcar routes in 1880 (Keeney 2017).

neighborhood to the northeast had a streetcar line (Figure 6). Lines covered the full length of the primary axial streets of Broadway and Colfax within the city proper, and routes extended four kilometers into the neighborhoods northwest of the South Platte River. These lines were built by many fiercely competitive startup companies. Competition was so intense, that on occasion one company would rip up the rails of another while building their own (Robertson and Cafky 1999, 2004).

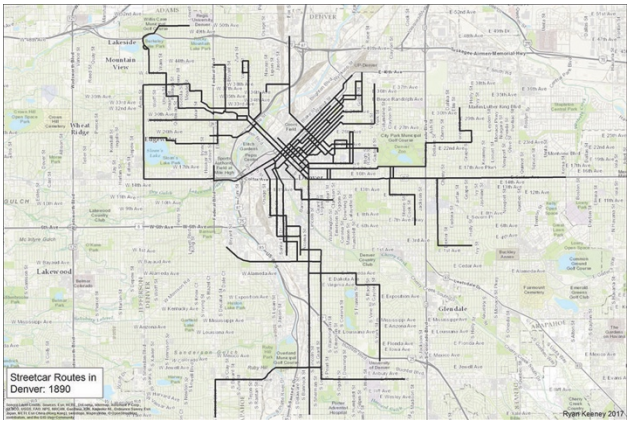

Figure 6. Denver's streetcar routes in 1890 (Keeney 2017).

New means of conveyance also appeared. Many of the new routes were cable cars (Figure 7). Driven by a central powerhouse, miles of sunken cables moved along next to the tracks, which the cable cars latched onto for propulsion. Additionally, steam engine streetcars were also built, including one which went out to the newly relocated University of Denver campus eight kilometers south of downtown. In the early 1890s the electric streetcar came on the scene,

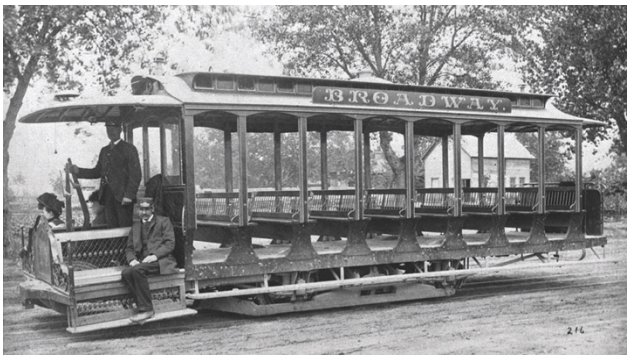

Figure 7. A cable car (Denver Public Library, Western History Collection, [X-27907]).

powered by overhead wires (Figure 8). By the time of the economic Panic of 1893, the electric streetcar had become dominant. The Denver Tramway Company owned the bulk of these superior electrified lines and was thus better positioned than its competitors (Robertson and Cafky 1999, 2004).

Figure 8. An electric streetcar (Denver Public Library, Western History Collection, [MCC-3848]).

The recession in 1893 largely brought a halt to street railway expansion and ushered in an era of consolidation. Companies merged, and redundant lines were taken out of service. By the new century the Denver Tramway Company emerged with a monopoly on streetcar service operation in Denver. Expansion picked up again in the early 20th century, but at a much slower pace. By this time automobiles had become affordable to a large swath of the population and the Tramway became aware of the threat it posed (Robertson and Cafky 1999, 2004).

In 1915 they commissioned a survey of the mode share of people traveling in and out of the central business district. Fifty-one percent rode streetcars, 38% walked, 13% drove automobiles, six percent rode bicycles, one percent drove motorcycles, and

one percent used horses. They also found that compared to 1914, streetcar patronage had dropped by nine percent and driving had doubled. However, in subsequent years the raw numbers of streetcar patronage again increased (Robertson and Cafky 1999, 2004).

It was around 1917 that the streetcar system reached its peak in terms of coverage (Figure 9) with the construction of a line to Barnum. After this was a long decline, with many lines being taken out, and the last new segment being built in 1923. Ridership peaked in 1910, with 87,819,000 passengers. At the time, 3,000 automobiles were present in the city. By 1928, the number of private automobiles had increased to 78,000 and streetcar ridership declined by 59% (Robertson and Cafky 1999, 2004).

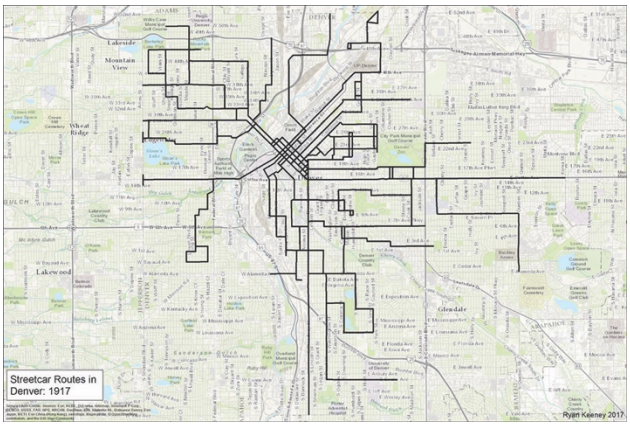

Figure 9. Denver's streetcar routes in 1917 (Keeney 2017).

The late 1920s and early 1930s marked the beginning of the conversion of many rail routes to bus routes but the Great Depression put a stop to this, stabilizing the rail system until 1940. At that time, trolley coaches, which are essentially buses powered by overhead electric wire, along with gasoline buses, began replacing some of the less heavily used streetcar routes. This conversion process didn't last long once the United States entered World War II. Gasoline and rubber were rationed due to the war effort, causing ridership to increase for the last time, and the system again remained stable until the end of the war in 1945 (Figure 10) (Robertson and Cafky 1999, 2004).

After the war, the economy boomed and a huge push for modernization in all aspects of life occurred. Many Denverites regarded the streetcars as ancient, noisy, and obsolete. With the advent of larger diesel

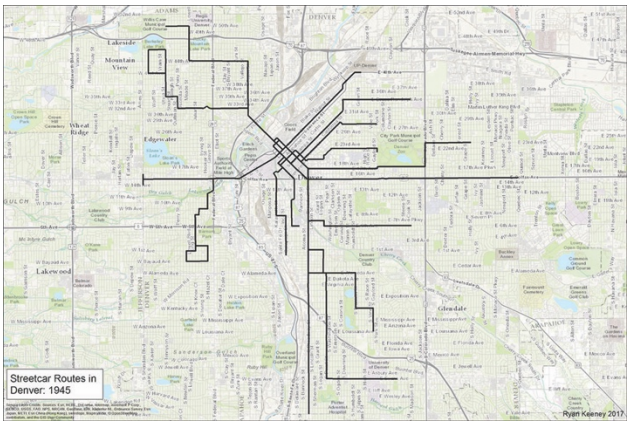

Figure 10. Denver's streetcar routes in 1945 (Keeney 2017).

buses, the removal of the streetcar lines accelerated, and the plurality in terms of transportation mode share that the streetcar had enjoyed since the late 1800s came to an end. By 1951, all streetcar lines were gone and the Denver Tramway became an all bus and trolley coach operation. The electric trolley coaches themselves were taken out of service in 1955 (Robertson and Cafky 1999, 2004).

Commercial Corridor Legacies

Denver once existed as a very compact city with development reaching only as far as the edges of the modern central business district. When the streetcar entered the picture, the footprint of the city began to expand along the streetcar routes. As late as 1933 the development of the city was tightly bound to them, existing as a grid of streets and alleys with rows of buildings clustered near the streetcar lines (Figure 11). Today, the spatial limit of the streetcar's influence can be inferred from the presence of back alleys, which fell out of fashion in favor of driveways after WWII. Except for New Urbanist developments such as Stapleton, the large majority of Denver's neighborhoods with alleys are within one kilometer of a historic streetcar route.

In the course of utilizing public transportation, a person must walk from their origin to the closest transit stop, and from the transit stop where they get off to their destination. This was daily life for most Denverites in the first half of the city's history (Robertson and Cafky 1999, 2004) and the built environment was configured to facilitate this. Additionally, commercial centers also developed on the same streets as the streetcar right-of-way. These businesses served their neighborhoods and allowed the people walking to and from the streetcars to purchase

Figure 11. South Denver in 1933 with streetcar routes. Washington Park top center (Keeney 2017).

goods and services before continuing on their way. Every part of Denver that developed during the streetcar era had at least one of these centers in walking distance.

Today, the streetcars are gone, but most of these commercial centers remain. The most obvious examples are the continuous corridors on wide arterial streets like Broadway and Colfax, but they are also scattered on more neighborhood-oriented streets like South Pearl near Florida (Figure 12). These neighborhood commercial nodes are of particular interest today because they lack the noisy and dangerous automobile traffic of bigger streets, are more pedestrian friendly, and are attractive for their quaint style of streetscape.

Figure 12. A SNCD on South Pearl Street in the Platt Park Neighborhood (Keeney 2017).

These Streetcar Neighborhood Commercial Developments (SNCDs) are defined as clusters or corridors of pedestrian-oriented commercial buildings (POCBs) located adjacent to an abandoned streetcar line on a road with fewer than four vehicle lanes (Figure 13) (Keeney 2017). Breaking down the term, "streetcar" refers to how these places were once configured around streetcar stops. The "neighborhood" means that they are primarily neighborhood serving. Therefore, big arterial roads with four or more lanes are excluded. Finally, the "commercial development" refers to how the buildings must contain some sort of enterprise, whether it is a store or an office. Pedestrian-oriented commercial buildings (POCBs) are commercial buildings clearly built with pedestrian access in mind. In contrast to modern big box stores, they are generally built flush to the sidewalk, but may also have a parking lot smaller than the building itself.

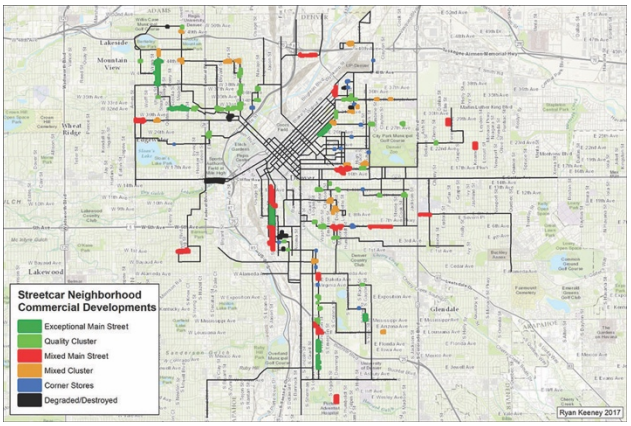

Figure 13. Map of Streetcar Neighborhood Commercial Developments (SNCDs) (Keeney 2017).

SNCDs come in many shapes and sizes and are therefore classified into six categories based on their size, their provision of POCBs, and their current status:

- *Exceptional Main Street*: These SNCDs have a historic main street feel and consist of an approximately 600+ foot street segment with no-parking-setback-POCBs covering at least 75% of the street frontage on both sides. Example: Gaylord & Mississippi (Figure 14a).
- *Quality Cluster:* More of a cluster than a corridor, these have greater than 75% of their street frontage lined with no parking-setback-POCBs, but are not large enough to qualify for "main street" designation. Example: 23rd & Dexter (Figure 14b).

Figures 14a-f. An Exceptional Mainstreet (top left), Quality Cluster (top center), Mixed Main Street (top right), Mixed Cluster (bottom left), Corner Store (bottom center), and Degraded SNCD (bottom right) (Keeney 2017).

- *Mixed Main Street:* These are large 600+ foot long corridors, but have more automobile oriented buildings mixed in. Example: 1st & Knox (Figure 14c).
- *Mixed Cluster:* Same building composition as a Mixed Main Street, but not large enough. Example: 11th & Ogden (Figure 14d).
- *Corner Store:* Any isolated POCB which contains multiple businesses. Single business corner stores are not accounted for. Example: Race & Kentucky (Figure 14e).
- *Degraded:* SNCDs where most of the buildings are vacant, have been torn down, or have been converted to residential uses. Unlike the other categories, Degraded SNCDs are not comprehensively surveyed in the Story Map. Example: Old West Colfax (Figure 14f).

Although the streetcars are now gone, the legacy SNCDs have functionally enhanced the walkability of their contemporary neighborhoods by increasing the proximity of property parcels to potential destinations. By comparing different neighborhoods through spatial analysis of the number of non-residential destinations each property parcel can access within a one-half mile sidewalk distance (Figure 15), it can be reasonably concluded that the presence of SNCDs

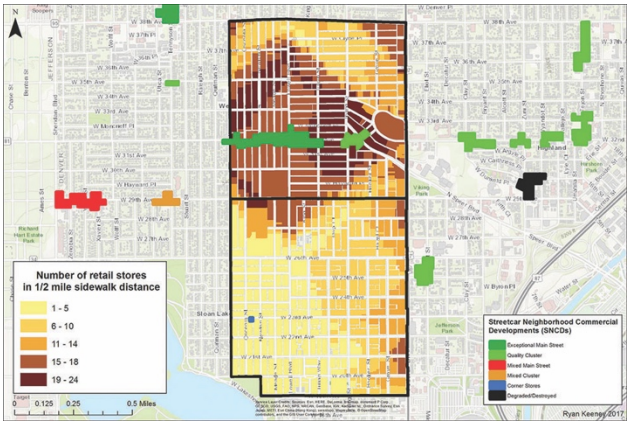

Figure 15. A walkability choropleth map of the Esri Story Map study areas showing total number of retail establishments each parcel can access in a 0.5 mile sidewalk distance (Keeney 2017).

improves peoples' ability to conveniently access goods and services by foot (Keeney 2017). This relationship between streetcar-oriented development and walkability is also borne out in the maps produced by Walk Score (Figure 16), a private company that produces a walkability index for neighborhoods throughout the United States.

Conclusion

Denver and cities around the country have experienced a resurgence, with more people choosing to live in walkable historic neighborhoods. Their

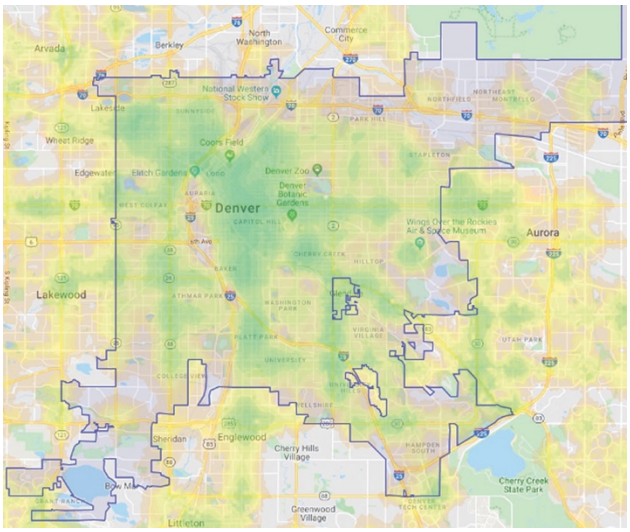

Figure 16. Walk Score map of Denver, with green meaning more walkable (Walk Score®, ChoiceMaps™, www.walkscore.com). This strongly correlates with the spatial extent of historic streetcar lines.

desirable spatial characteristics exist in part because these places were originally built to facilitate walking and transit trips. This is the case in central Denver, which primarily developed around these modes of travel for the first half of its history. The streetcar system operated for 78 years and spawned streetcar neighborhood commercial development at many of its stops. These districts are a critical factor in the walkability of Denver's streetcar suburbs, and this is one of the primary drivers of the contemporary desirability of these now central urban neighborhoods. The research project upon which this chapter is based (Keeney 2017) was the first to fully digitize the spatial network of Denver's historic streetcars and the SNCDs, garnering local news media attention[2]. Hopefully this work can influence better public understanding of the relationship between Denver's history and its current built environment, perhaps even resulting in a positive impact upon the ongoing growth and development of the city today.

Notes

1. The full URL for the *Denver's streetcar legacy and its role in neighborhood walkability* Esri Story Map is: https://dugis.maps.arcgis.com/apps/MapSeries/index.html?appid=00a2d498a2ac4c58ad140ac306110213.
2. The full URLs of several local media reports: *Denverite*: https://denverite.com/2017/08/12/denvers-cute-commercial-districts-common-streetcars-according-map/. *9News*: https://www.9news.com/article/news/history/take-a-trip-back-in-time-with-a-map-of-denvers-old-streetcar-lines/73-457776712. *Westword*: https://www.westword.com/news/denvers-streetcar-legacy-maps-out-78-years-of-public-transit-history-9272273.

References

[CNU] Congress for the New Urbanism. 2020. The movement. Accessed January 11, 2020. https:// www.cnu.org/who-we-are/movement.

Fishman, R. 2008. New urbanism in the age of reurbanism. In: Haas, Tigran, ed. *New urbanism and beyond: Designing cities for the future*. New York: Rizzoli.

Gilderbloom, J. I., W. W. Riggs, and W. L. Meares. 2015. Does walkability matter? An examination of walkability's impact on housing values, fore-closures and crime. *Cities* 42:13-24.

Keeney, R. 2017. *Denver's streetcar legacy and its role in neighborhood walkability*. MA capstone project, University of Denver.

Morris, A. E. J. 2013. *History of urban form: Before the industrial revolution*. London: Routledge.

Muller, P. O. 2017. Transportation and urban form: Stages in the spatial evolution of the American metropolis. In *The geography of urban transportation,* eds. G. Giuliano and S. Hanson, 4th ed. New York: Guilford Press.

Murray, J. 2019. Denver's population has grown by nearly 20 percent since 2010—and it's picking up again. *Denver Post,* April 18. Accessed January 11, 2020. https://www.denverpost.com/2019/04/18/denver-population-growth-census/.

Redfin. 2016. How much is a point of walk score worth? Accessed January 11, 2020. https://www.redfin.com/blog/how-much-is-a-point-of-walk-score-worth.

Robertson, D. and M. Cafky. 1999. *Denver's street railways* 1:1871-1900. Denver, CO: Sundance Publications Ltd.

Robertson, D. and M. Cafky. 2004. *Denver's street railways* 2:1901-1950. Denver, CO: Sundance Publications Ltd.

Zillow. 2020. Denver Home Prices & Values. Accessed January 11, 2020. https://www.zillow. com/denver-co/home-values/.

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URBAN SPACE AND LOCAL NETWORKS: DENVER BREWERIES 1859-1876

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Denver's beer history runs parallel to the history of the city and intersects on multiple levels with the identity of the city. Most famously, Coors Brewery has their name prominently displayed on billboards, buildings, stadiums, and is woven into the fabric of Denver and Colorado. Yet, Molson Coors, the parent company of Coors Brewing Company, announced a major move from its Denver headquarters to Chicago in the fall of 2019 (Sexton 2019). The company promised to continue operation of its Denver-area enterprises, most notably the original brewery in Golden. Nevertheless, this migration east seemed to strip Denver of the Coors identity that has long dominated Denver's beer industry. Adolph Coors' brewery, which opened in 1873, was one of two Denver breweries to make it through Prohibition, and instrumentally shaped Denver's history and identity until the present day.

The relocation of Coor's brewery offers a great opportunity to examine pre-Coors Denver brewing. Although, a vigorous and active brewing industry functioned before Coors opened his brewery, it is important to note that Coors built his brewery in Golden rather than Denver, a separation of 20 miles. Despite this, breweries proliferated far from the shadow of Coors. Denver breweries from 1859 to 1876 offer insight into industrial spatial and economic obstacles that beset a multitude of businesses and which had no simple answers. These obstacles, their origin, problem, and solution, reveal a world where distance mattered and illustrate the foundations of Denver's beer history.

Late nineteenth-century Denver brewers expose the multitude of local, regional, and national networks that existed in Denver during this time. Railroads, agricultural hinterlands, and booming population can all be examined through breweries. Here, the focus will be on Denver breweries' spatial and financial options, the ensuing choices owners made, and the impact these decisions had on their success from 1859 to 1876. Much of the discussion will focus on west-side breweries, which produced more beer and lasted for decades rather than their east-side counterparts, who existed for single-year durations.

Much of the data comes from Denver Directories—an imperfect source of information. These were compiled and published in part by Corbett & Ballenger, who are the authors I cite when I draw from directory information. The directory notes names, occupations, and addresses of Denver denizens, though not everyone supplied all this information. Therefore, I have assumed that people would rather give their place of work than home address, and when the address states vague or ambiguous language (such as "on the Corner of X and Y") I placed them on the southwest corner of the intersection. The points are placed on a georectified 1873 map of Denver that also poses issues, such as the two perpendicular Cheyenne Sts. Further, there is a glaring gap in the directories from 1866 to 1871, a hole filled through assuming a continuity for breweries that exist on both sides of the divide and newspaper reports on the beer market during these years.

Gold, or at least the allure of finding gold, drew miners and prospectors to Cherry Creek at the foot of the Rocky Mountains in 1858. Prospectors followed the streams into the mountains to find their payloads, while others less adventurous but no less enterprising built up two competing towns. The first, St. Charles—later called Denver City, then Denver—was built on the northeast side of the creek in September 1858. The next month Auraria was built on the opposing side. From these beginnings, Denver emerged and swallowed up both sides of the water. City planners laid out lots, merchants set up shops, and people came across the Great Plains to buy mining supplies before trying their hand at prospecting. Those that were successful spent their gold dust in Denver, which then sent the gold east to purchase additional mining and town-building supplies. Newspapers, like William Byer's *Rocky Mountain News*, wrote stories, reported the news, and appealed to Americans to come to the new city. Over the years, diverse business emerged

contributing to Colorado's territory status in 1861 and statehood in 1876 (Leonard and Noel 1990).

When miners sought Colorado gold in 1858, brewers followed and brought skills to brew golden lager. Though the 1860 Census reported five brewers as compared to roughly 22,000 miners, by 1880 154 brewers hydrated the approximately 200,000 Colorado inhabitants (U.S. Census Bureau 1860). Solomon & Tascher in Denver opened the first official brewery and in 1859 ran an advertisement promoting their brewery and their soon-to-be-tapped lager beer (*Rocky Mountain News* 1859). Lager, a derivative of *lagern* a German word meaning "to store" beer is deeply rooted in Germanic brewing heritage (Pavsler and Buiatti 2008). Sixteenth-century Bavarian monks first practiced brewing in the fall and cellaring—or lagering—their beer over winter for the spring (Pavsler and Buiatti 2008). The fact that Denver's first beer brewed was lager rather than ale or porter suggests German roots, rather than English, Irish or other roots in Denver brewing.

Of these German immigrants, 1200 lived in Colorado out of a population of 31,000 (U.S. Census Bureau 1860). Although only four percent of the overall population, German immigrants had an outsized influence on brewing. For example, in 1870 Colorado, of the 54 people involved in brewing and malting, 34 were German. These men were also among Denver town boosters and wrote pamphlets advertising Denver to Germans abroad (Dorsett 1977). Americans—eight in total—were the next largest category, some likely naturalized Germans (U.S. Census Bureau 1860). This is representative of national statistics; in 1870 the U.S. Census reported 6700 German brewers to only 2700 American (U.S. Census Bureau 1870).

The first brewery, the Rocky Mountain Brewery, is illustrative of the ethnic character of Denver's brewery business. Salomon, a Polish immigrant and an exception, partnered with Charles Tascher, a German immigrant, to open the Rocky Mountain Brewery in 1859. After a few months Tascher left the partnership, replaced by Charles Endlich and John Good (born Guth in Alsace-Lorraine). Salomon left in 1861 and Endlich died in 1864, leaving Good in charge. Good brought Phillip Zang, also a German immigrant, into his company as a brewer and later sold the company to him (Coel, Barker, and Gilleland 1985; McLeod 2016). German immigrants controlled Denver brewing similar to brewing capitals in the Midwest.

At the capital city and hub of industry and trade, Denver brewers recognized the crucial function location and space played in their businesses. Large brewers—namely John Good, Phillip Zang, and Moritz Sigi—benefitted from access to enhanced capital and economies of scale, but that belies many underlying facets of their success. Beyond economic factors, their ability to negotiate spatial relationships within and outside Denver was profound. Better than their smaller competitors, big brewers positioned themselves near essential sources of water, distanced themselves from competition, and structured hierarchical labor.

Water

Water plays a vital role in the development and concentration of beer; no matter the beer type or style, it comprises over 90% of beer. Denver's birth at the confluence of the Cherry Creek and the South Platte River supplied the denizens with many of their water needs. Yet, transporting water requires tremendous labor and expense, and as such establishing breweries near clean water sources was a crucial consideration of early breweries (Gatrell, Nimeth, and Yeager 2014). While weight and infra-structure is a consideration for all ingredients, water was by far the heaviest and most used component.

Today, brewing 25 gallons of beer requires approximately 100 to 160 gallons of water, though often more in smaller breweries (Lewis and Bamforth 2007). Nineteenth-century Denver brewers likely found themselves on the higher side of this range due to equipment and technology differences. Therefore, the approximately 775,000 gallons of beer brewed in 1870 necessitated around 4,650,000 gallons of water—a burden around 37,000,000 pounds (Gatrell, Nimeth, and Yeager 2014; Lewis and Bamforth 2007). Every yard brewers could shrink between them and water was a worthy investment.

Proximity to water was especially crucial to large scale brewing. Phillip Zang's Brewery, John Pemberton's Denver Ale and Beer Brewing Co., and Moritz Sigi's Colorado Brewery are located on the west side (Figure 1). These breweries lasted years, some decades, and produced the majority of beer in Denver. Between Cherry Creek, the South Platte River, and the Mill Ditch system, they were near several sources of water. The latter, the closest to their brewhouses, likely provided west-side brewers with most of their water. Across the creek, smaller breweries run by individual brewers, such as Alex

Davidson and Lyman (or Lynn) Parkhurst, had short longevity and low production. For example, in 1870, Lynn produced 2,700 gallons of ale. Though considerable, and gallons ahead of the lowest producer, it amounted to less than four percent of beer brewed that year.

Figure 1. Denver breweries 1859-1876.

Carrying water the shortest distance possible meant each trip took less time and effort, cut down on labor costs, and allowed brewers to produce batches of beer more quickly. Except for City Brewery, small scale breweries averaged 620 meters from their nearest water source, typically Cherry Creek. Conversely, west-side breweries averaged 223 meters away from the ditch that provided them water (Figure 1). Collecting, rolling, and filling mashtuns with thousands of gallons of water over the course of a year would be onerous at best. Larger breweries employed general laborers who could do this work instead of the brewers, but for single-employee breweries this was not an option.

The qualities of water such as its impurities, pollutants, or mineral content greatly influence beer's taste and purity. Like many rivers and streams prior to municipal sewage systems, however, Denver's water sources were heavily polluted. Denver did not develop sewage until the 1880s and even then, the solution lagged behind the need. By 1870, sewage run-off into the South Platte led to a nauseous stench throughout the area (Dorsett 1977). Phillip Zang was elected to the Committee on Drains and Sewers in 1874 as a testament to the substantial impact on brewers (*Denver Daily Times* 1874). Zang's election to an office devoted to clean water suggests the importance of clean water to brewers and consumers as well as the prominence that west-side brewers had attained. His business was sufficiently profitable and managed that he was able to take the time to volunteer to craft water and sewage policy, an opportunity not available to smaller brewers working on short margins.

Saloons

Cherry Creek successfully bifurcated small from large breweries and isolated large breweries from saloons and other liquor vendors. Although competition was common between breweries, brewers competed and cooperated most closely with saloons as well. Like their counterparts elsewhere in the Rocky Mountain West, saloons and taverns proliferated in Denver (Hogan 1990). Distance between brewers and saloons held several complications depending on the size of the brewery. At the forefront was the consistency of saloons' location over almost a decade (Figure 2). The mean center of all saloons in 1866 and 1873 are a narrow 170 meters apart. The number of east-side brewers resides within the first standard deviation—68%—of 1873 saloons' mean center (Figure 3). As can be seen, from 1859 to 1876 several breweries opened, and closed, within this area. The proximity of saloons to these brewers sug-gests a benefit for their distribution and a good decision by the smaller brewers.

Small east-side brewers' closeness to saloons provided a handful of benefits. First, being next door to saloons offered a way to advertise to walking customers, and perhaps entice passersby to opt for beer rather than spirits. Also, saloons offered beer, and reducing the distance from brewer to saloon allowed easier transportation and reduced costs. Additionally, some smaller breweries were attached to certain saloons which allowed people to purchase beer for home consumption (McLeod 2016). Small breweries, then, made a conscious decision to sacrifice easy access to water in exchange for proximity to their customers.

Figure 2. Denver saloons, 1866 and 1873.

The survival of small breweries depended heavily on direct contracts with saloons. That these breweries rarely lasted more than a year implies saloon contracts were for a similar duration. These brewers may have brewed only as a temporary stop-gap measure and after a year moved onto other occupations. Yet, brewing requires significant equipment and technical knowledge, so even though it may have been a temporary fix, imaginably east-side brewers would have preferred a longer run.

Conversely, the harmful impact saloons had on these small breweries is clear as none lasted more than a year. Large industrial brewers took up considerable space and could not be neighbors to saloons. West-side brewers chose to be further from saloons and closer to water with space to grow. They circumvented their distance through hiring teamsters and laborers to transport barrels to saloons. Ultimately, they outcompeted and eliminated the opportunity for small brewers to operate, partially through creating a buffer between similar industries facilitating long-term growth.

After a small brewery closed, saloons contracted with another small brewery, or, increasingly into the

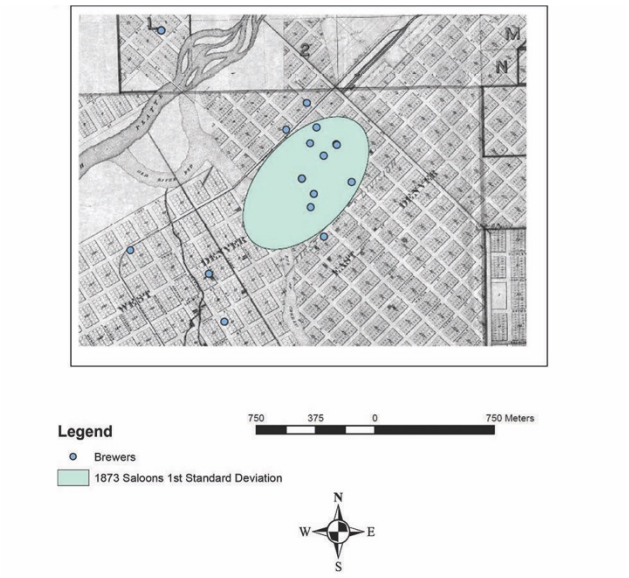

Figure 3. Brewers with 1873 saloons: First standard deviation.

1870s, bought in bulk from the west-side brewers. By 1876 the barriers to start a new brewery were prohibitive due to the near monopolization west-side Denver brewers had established. The high production, distribution, and power big brewers created allowed them to dominate the local market, and even distributed to Laramie, Wyoming or Salt Lake City, Utah (*Rocky Mountain News* 1873).

Labor

Skilled brewers and maltsters were an indispensable element of the brewery, but to run an efficient beer factory—as many west-side brewers were fast becoming—the brewery needed facility management, white-collar positions, and an abundance of labor. Of the 100 workers involved in brewing from 1871 to 1876, 40 were brewers—almost half of all workers in brewing (Corbett & Ballenger). Skilled expertise was still the bedrock of brewing, but west-side breweries incorporated workers with financial acumen rather than brewing finesse. As breweries expanded, they contended with the need to augment their staff effectively and maintain workers in a transitory labor environment.

Supervisors and foremen entered breweries during this industrial transition. They likely scheduled workers, arranged beer transportation, ensured adequate supplies, and communicated with owners and workers. Some brewers and maltsters transitioned into these positions, such as Frederick Holdrer—a brewer at Colorado Brewing Co.—and George Smith—a maltster at Rocky Mountain Brewery—

who were promoted to foreman at their breweries (Corbett & Ballenger). These men knew the process of malting and brewing, but more specifically knew their respective brewery's workers, equipment, and recipes.

More often, foremen came from outside the company. Over this period, Colorado Brewing Co. hired a manager and a foreman in addition to their brewer. Rocky Mountain Brewery had two foremen on their staff, one acquired from Denver Brewing Co. (Corbett & Ballenger). These men, similar to the unskilled workers, often did not work for more than two years at a brewery. Breweries recognized a need for these positions as they industrialized, but it seems they were still working out how to fill these roles. Adolph Leininger at Denver Brewing Co. is an interesting counterexample. He was their supervisor and foreman from 1873 to 1876, perhaps longer, and held one of the longest positions besides the owners.

The increasingly complex workforce necessitated additional financial tools and effort. As a result, some breweries hired office staff that worked as bookkeepers, secretaries, and treasurers. Moritz Sigi hired his relative J.W. Sigi to work as a bookkeeper in 1874 and 1875. Zang employed a man in 1876 for the same purpose. Bates' Denver Brewing Co. hired Charles Johnson as treasurer and secretary from 1873 to 1875 at the same time as a massive physical expansion (*Rocky Mountain News* 1870).

In a competitive market for skilled labor, Denver brewers and maltsters often changed employers or roles within the same brewery. Their specialized labor was more crucial to the success of the breweries than unskilled laborers. As such, directories report maltsters working at various breweries year to year (Corbett & Ballenger). A few reasons may explain these shifts: they were poached, fired, or fell out with the head brewer. Whatever the reason, they all point to the competition between breweries and the constant need for skilled labor. Further, they emphasize two trends within Denver and American breweries. First, malting slowly dissolved as a craft and was replaced more and more by machines (H.S. Rich & Co. 1974). Secondly, as a result, middle management emerged in breweries to oversee machines and laborers.

Laborers comprised a transitory segment of the workforce, hardly ever staying for long but providing indispensable work. Sigi purchased a building, renamed Sigi's Hall, at 244 10th St. in west Denver. Sigi, along with many Colorado Brewery workers, listed 350 10th St. in the directory as their personal or business address. The brewery was at the corner of Larimer and 10th St. (Corbett & Ballenger). In either event, he was aware of the risks of losing workers to his competitors and attempted to integrate his workers closer to his brewery by shortening their commute and being their landlord.

Keenly aware of the transitory and competitive market for labor, brewery owners sought out three levels of workers. First, they needed skilled brewers and maltsters who created beer. Second, they needed laborers to stir, mix, carry, and distribute the product. Finally, as they produced more beer, west-side brewers hired supervisors, managers, and bookkeepers who recorded and organized the increasingly large and complex operations. Only west-side brewers walked through each level of employment on the way to building major beer-producing businesses.

Conclusion

Denverites enjoyed their beer, and numerous entrepreneurs endeavored to meet that need. Most were small scale breweries, located along city streets next to saloons and taverns, who hoped proximity to customers would negate their distance from production resources. To say these businesses failed is somewhat unfair, as many people in early Denver transitioned easily between industries and moved between the mountains and Great Plains frequently. Instead, these small brewers realized the difficulty in producing beer at a profitable level given their small operations. Larger breweries located on the west side of the city emerged as giants in the industry, far out producing upstart brewers and made it increasingly difficult to break into the beer business. By 1876 only the large breweries existed in Denver, and, although other Colorado cities had breweries, began to distribute their products across the Front Range and into the mountain towns. From 1876 to 1880 Colorado breweries led by Denver ones increased their production from 710,000 gallons to 1.5 million gallons (One Hundred Years of Brewing 1903).

Long-lived Denver brewers realized early on that distance mattered. They positioned themselves within the city to most efficiently connect to networks of resources while maintaining a distance from competetors. Their mark on the city is indelible, indeed the Rocky Mountain Brewery the first in Colorado, survived many permutations and today stands as the Tivoli in the same place it has for over one hundred years. It is an integral part of a campus shared by Metropolitan State University of Denver, the University of Colorado Denver, and the Community

College of Denver today. These schools offer brewing courses and lean into the rich history of Denver brewing. Denver is dotted with testaments to the long brewing history, and today brewers continue to produce beer for Denver's denizens and build upon the generations of brewers who contributed to the city.

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References

Coel, M., J. Barker, and K. Gilleland. 1985. *Tivoli: Bavaria in the Rockies*. Boulder, CO: Colorado and the West.

Corbett, H. and Co. 1859-1876. Corbett & Ballenger's Annual Denver City Directory. Item ID 10981477. Denver. Abbreviated as DDD.

Denver Daily Times. 1874. Committees. April 24.

Dorsett, L. 1977. *The Queen City: A history of Denver.* Boulder: Pruett Publishing.

Gatrell, J. D., D. J. Nimeth, and C. D. Yeager. 2014. Sweetwater, mountain springs, and Great Lakes: A hydro-geography of beer brands. In *The geography of geer: Regions, environment, and societies*, ed. M. Patterson and N. Hoalst-Pullen, 89-98. N.Y: Spring.

Hogan, R. 1990. *Class and community in frontier Colorado.* Lawrence, KS: University Press of Kansas.

Leonard, S. and T. Noel. 1990. *Denver: Mining camp to metropolis.* Niwot, CO: University Press of Colorado.

Lewis, M. J. and C. W. Bamforth. 2007. *Essays in brewing science*. Boston: Springer.

McLeod, R. W. 2016. *Ghost breweries of Colorado.* Arvada, CO: CreateSpace Independent Publishing Platform.

One hundred years of brewing: A complete history of the progress made in the art, science and industry of brewing in the world, particularly during the nineteenth century. 1903. Supplement to *The western brewer.* Chicago: H.S. Rich & Co.

Pavsler, A. and S. Buiatti. 2008. Lager beer. In *Beer in health and disease prevention*, ed. V. R. Preedy Burlington, MA: Elsevier.

Rocky Mountain News. 1870. January 8.

———. 1873. May 28.

Rocky Mountain News Weekly.1859. Lager. November 3.

Sexton, J. 2019. Molson Coors closing Denver office, cutting 500 jobs internationally and moving its headquarters to Chicago. *Denver Post*, October 30.

U.S. Census Bureau. 1870. Census: Volume 1. The statistics of the population of the United States.

———.1860. Classified population of the states and territories, by counties on the first day of June, 1860.

———.1880. Statistics of the popu-lation of the United States.

———.1860. Recapitulation of the Tables of Population, Nativity, and Occupation, 1860.

———.1870. The number of persons in each state and territory engaged in each selected occupation and class of occupations, with distinctions of ages and sex and of nativity, 1870.

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