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THE ECOLOGY OF ACEQUIAS IN THE MORA VALLEY: PATTERNS, PROCESSES AND PLACE-BASED KNOWLEDGE

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THE ECOLOGY OF ACEQUIAS IN THE MORA VALLEY: PATTERNS, PROCESSES AND PLACE-BASED KNOWLEDGE

BY

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DISSERTATION

Submitted in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy

Ph.D. in Biology

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DEDICATION

For my children:

Daniel Joseph Rupert

and

Aurora Corinne RuPert

As proud and happy as I am of this

I am far more proud and happy for the two of you.

Always.

I love you both so much.

ABSTRACT

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In northern New Mexico, early settlements were clustered for protection of the people and access to water for domestic and agricultural uses was critical to their success. Irrigation ditches, known as acequias, brought water to the people, and were central to community life. These earthen ditches of varying lengths were built between one hundred and several hundred years ago, and most are still operational today. They divert water away from natural streams and across the landscape, through a system of man-made channels, until the unused water is diverted back into natural watercourses. These lateral channels appear to function as extensions of the riverscape, but flow intermittence and physical qualities are managed, and most natural disturbances are dampened. Cultural studies have suggested that acequias have a positive influence on the local ecosystem by increasing floral and faunal biodiversity, extending the riparian zone, and protecting the hydrology and ecology of the watershed, but no rigorous scientific studies have been conducted. This project asks: “What are the effects of this diversion of water on the ecology of an area from a management, local history and ecological perspective?” We examined the influences of an acequia system on a catchment in Mora, New Mexico to determine to what extent these assumed benefits are realized. Acequias are managed in such a way that they respond more quickly to changes in climate and demands for water than larger water systems. Over time, they create a stabilized environment that allows local landowners to continue using farmland while repairing damage caused by overuse of cropland in the past. Finally, a look at the aquatic macroinvertebrate communities of the perennial river and associated intermittent acequias shows that these acequias have a structure comparable to that of intermittent river systems. This research suggests that place-based knowledge in northern New Mexico has aided in creating an extension of the natural waterways that may benefit both the water users and the local ecosystem.

TABLE OF CONTENTS

LIST OF FIGURES

From Introduction:

From Chapter 1:

From Chapter 2:

From Chapter 3:

From Summary:

LIST OF TABLES

From Chapter 1:

From Chapter 2:

From Chapter 3:

INTRODUCTION

UNDERSTANDING PLACE:

EXPLORING PATTERN AND PROCESS IN AN ECOLOGICAL SYSTEM

A unique aspect of agriculture in northern New Mexico is the centuries-old irrigation ditches, or acequias. Communities were built around the need for water, and the acequia system was central to community life. Acequias are earthen ditches of varying lengths, and most are still operational today. They divert water as it comes off the watershed, away from natural streams and across the landscape, through a system of man-made channels, until the water is diverted back into the natural watercourse. These lateral channels, while appearing to function as extensions of the riverscape, are highly managed and most natural pulses are dampened. This dissertation asks: “What are the effects of this diversion of a natural resource on the ecology of an area and, in particular, on the ecological connectivity in the valley?” Ecological connectivity is defined as the “connectedness of ecological processes across multiple scales” (Lindemayer and Fischer 2006). Particular to my study is a second question. Diversion of water into the acequias in the Mora Valley has resulted in a 3.4 km reach of the Mora River drying for extended periods of weeks to months. So we ask: “What are the ecological effects of this drying of the river?” Cultural studies have suggested that acequias have a positive influence on the local ecosystem by increasing biodiversity, extending the riparian zone, and protecting the hydrology and ecology of the watershed (Rivera 1990, Rodriguez 2006). However, there have been no rigorous scientific studies done that explore these claims. By examining the influences of an acequia system on a single, local catchment, we will be able to start to determine to what extent these assumed benefits to local ecology are realized.

A series of questions and hypotheses drove this investigation (Figure 1). The first is addressed in Chapter 1, which looks at how place-based knowledge of the structure and function of acequias, often called “acequia culture”, drives management of local water resources, and how this affects the landscape. The chapter discusses how these local management practices compare to regional management policies. This chapter also addresses how predicted climate change can be ameliorated by acequia culture.

Chapter 2 looks at past land use changes in the region. This is critical because land use is predicted to have a greater impact on water resources than climate change in this region, at least in the immediate future, and should to be addressed in planning and protecting ecosystems, both natural and managed, from the effects of future change.

Chapter 3 moves away from the social-ecological aspects evident in the first two chapters and looks at the ecology of the aquatic macroinvertebrates that inhabit the streams and acequias in the Mora Valley. Specifically the chapter looks at diversity and community patterns and how disturbance modification on the acequias affects them and determines if acequias can be assumed to resemble intermittent rivers and ephemeral streams (IRES).

Following the three chapters, a summary is provided linking the three aspects of this project together and addressing what this has to do with the health of the aquatic system in the Mora Valley. We look at what future research is needed to further our knowledge of acequias and how that knowledge will be used to affect the landscape and the people who manage it.

Figure 1. A generalized diagram showing how a local case study can be used to ask larger questions about IRES (Intermittent Rivers Ephemeral Streams).

LITERATURE CITED

Lindenmayer, D.B. and Fischer, J. 2006. Habitat fragmentation and landscape change: An ecological and conservation synthesis. Island Press, Washington D.C.

Rivera, J.A. 1998. Acequia culture: Water, land and community in the Southwest. University of New Mexico Press, Albuquerque, New Mexico.

Rodriguez, S. 2006. Acequias: Water sharing, sanctity and place. SAR Press, Santa Fe, New Mexico.

CHAPTER ONE

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ACEQUIA CULTURE BENEFITS ECOSYSTEM FUNCTION IN THE MORA VALLEY

Shannon M. Rupert[1]

ABSTRACT

Water resources in the Southwest U.S. will become more limited in the coming decades due to increased demand, shifts in land use, and climate change. While we struggle to find ways to adjust governmental water management policies to meet these challenges, in many small communities in northern New Mexico, water is still managed locally using traditions that are sometimes hundreds of years old. In the Mora Valley, acequia management practices have reduced the natural flow of the Mora River such that a 3.4 km section is dry most of the year. In contrast to what would seem an unhealthy situation, the ecology of the river below this dry stretch appears much as it does above the diversion, suggesting that the connectivity created by the acequias allows those managing them to react to natural pulse and press events as they occur. Using a social-ecological framework, a comparison of local water data and management practices to that of larger government-managed projects shows that culturally based community management systems have a greater flexibility and quicker response to both short and long term perturbations. These community practices have a greater influence on water management in the Mora Valley than governmental policies, and have the potential to ameliorate problems normally associated with reduced or intermittent stream flow.

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New Mexico has the lowest water to land ratio in the United States. Only 0.2 percent of the state's almost 3.5 million hectares, or about 60,600 hectares, are surface water sources such as lakes and rivers (U.S.G.S. 2012). Not all the water in these surface bodies belongs to the people of New Mexico. Water sharing agreements, or compacts, with other states make it necessary for us to deliver part of our water across state lines. Demand for this limited natural resource is only expected to increase with population growth, land use shifts, and climate change. It is not hard to understand why New Mexicans take their water seriously.

Any study of water in New Mexico has a human component. This is especially true in northern New Mexico, with its long history of human occupation. There is no place in northern New Mexico where the original biodiversity of the region has not been altered (Debuys 1985). Even on the steepest mountain slopes, past grazing has affected current distribution of flora. And acequias, traditional earthen irrigation ditches, have been diverting water away from stream channels and across the landscape for sometimes hundreds of years. It is a landscape intricately linked to people, a place where ecology and culture collide. And because cultural traditions are still a strong part of everyday life in northern New Mexico, it is perhaps the best place to understand this connection between the life of the land and that of its people. The emerging discipline of social-ecology gives us a place to begin.

Most ecologists focus on systems in which the human component is discounted, minimized, or considered in the context of how it impacts an otherwise natural system. However, in the past half-century, humans have altered ecosystems more than at any other time in history (Collins *et al.* 2011). This means we can no longer ignore the impact of human behavior and the outcome of those behaviors as they affect ecosystems. This interdisciplinary way to look at systems is opening up new questions and giving us new answers. Most simply defined, social-ecology looks at the interactions between human populations and communities and their environment. Social-ecology studies should produce actionable science that can be used to shape political and environmental decisions before human impact has a devastating effect on an ecosystem.

Social-ecology as a discipline is much more established in the social sciences than in ecology. As a result, most published research leans heavily on social science methodology. Social scientists have developed complex frameworks for analyzing how social conditions affect things such as natural resource depletion and ecosystem health (Cox 2008). One recent study by Cox (2010), for example, investigated the social-ecology of the acequias in the Taos Valley. While the research is rigorous using accepted social science methodology, it illustrates the need for more collaboration between social scientists and ecologists. Cox used the single dependent variable of crop production, using the Normalized Difference Vegetation Index (NDVI), to equal collective action. From an ecological perspective, there are two problems with this. First, using a remotely sensed estimate of vegetation cover to determine crop production in areas where flood irrigation is practiced will result in an overestimation of production. Second, Cox asserts that the Taos Valley is dependent on growing crops as his justification for using this variable. Data from the USDA Census of Agriculture show that contrary to this assumption, Taos County is not dependent on farming and indeed, the average farm in Taos County loses money each year (2007). This romanticism of farming in northern New Mexico persists in the face of a changing landscape. It is perpetuated for myriad reasons, the most justifiable being that it is the cultural heritage of the Native and Hispanic peoples who have shaped this land.

Social questions about acequias often focus on cultural values and how traditional management and use of the acequias create sustainability and healthy landscapes. Cultural studies suggest that acequias have a positive influence on the local ecosystem by increasing biodiversity, extending the riparian zone, and protecting the hydrology and ecology of the watershed (Rivera 1998, Rodriguez 2006). Biophysical research on acequias has been limited in the past and has mainly focused on hydrology (Fernald *et al.* 2007, 2006) and GIS mapping. Along with our study on the ecology of the acequias in the Mora Valley, two other current projects (Roybal 2012, New Mexico EPSCoR 2011) demonstrate a shift toward social-ecological thinking about acequias.

An example of a proposed framework for social-ecological studies is the Pulse-Press Dynamics (PPD) framework of Collins *et al*. (2011). This framework suggests that pulse-press events and ecosystem services can be used as links between the social domain and the biophysical domain. Pulse events are those that occur suddenly, while press events happen slowly and pervasively. Both pulse and press events can create disturbance in the two domains, and for each the resistance and resilience of the component can be studied. Ecosystem services create a linkage between the domains by their very nature. The definition of an ecosystem service is a structure or function within an ecosystem that benefits humans. The PPD framework provides a way to examine natural systems with humans in a holistic way.

A PPD framework for the acequia system in the Mora Valley demonstrates how this works (Figure 1). The social domain of the acequia has two components. Human behaviors are those management decisions made by using place-based knowledge passed down through generations. Human outcomes are the sustainability of these community-based practices and the benefits to the overall health of the landscape. Likewise, there are two components to the biophysical, or for the purpose of our study, the ecological domain. Patterns such as community structure and biodiversity make up one component, while processes like hydrologic flow and discharge make up the other. Disturbances in the form of presses and pulses create feedbacks that push these components in a given direction. The major pulses in this system are short-term drought, spring runoff, the summer monsoonal rains, and nutrient inputs, such as fertilizers from farming and ranching, domestic use, and a fish hatchery. Presses are long term changes related to climate change, shifts in land use, and population growth. The social components react to the presses and pulses; these in turn shape the patterns and processes of the ecosystem, which dictate the ecosystem services used by the people. In the Mora Valley, the ecosystem services are hydrologic connectivity, irrigation that results in crops, and a continuation of cultural traditions and values. While there may be other components to this proposed PPD framework, we are limiting the scope of this article to those listed here.

The overall question is: Are current water management practices, both community and governmental, affecting the ecology of the acequias and streams within the Mora Valley? We suggest that the answer is yes. Each of the four hypotheses listed in Table 1 will be addressed in a sub-section below.

Table 1. List of hypotheses (H) as they relate to the overall question of how current water management practices affect the ecology of the acequias and streams within the Mora Valley.

H1 Water resources have become more limited in recent decades, but acequia management has not.

H2 Current acequia management practices have reduced the natural flow of the Mora River.

H3 Community practices have a greater influence in water management than governmental practices.

H4 These community management practices ameliorate problems normally associated with reduced streamflow.

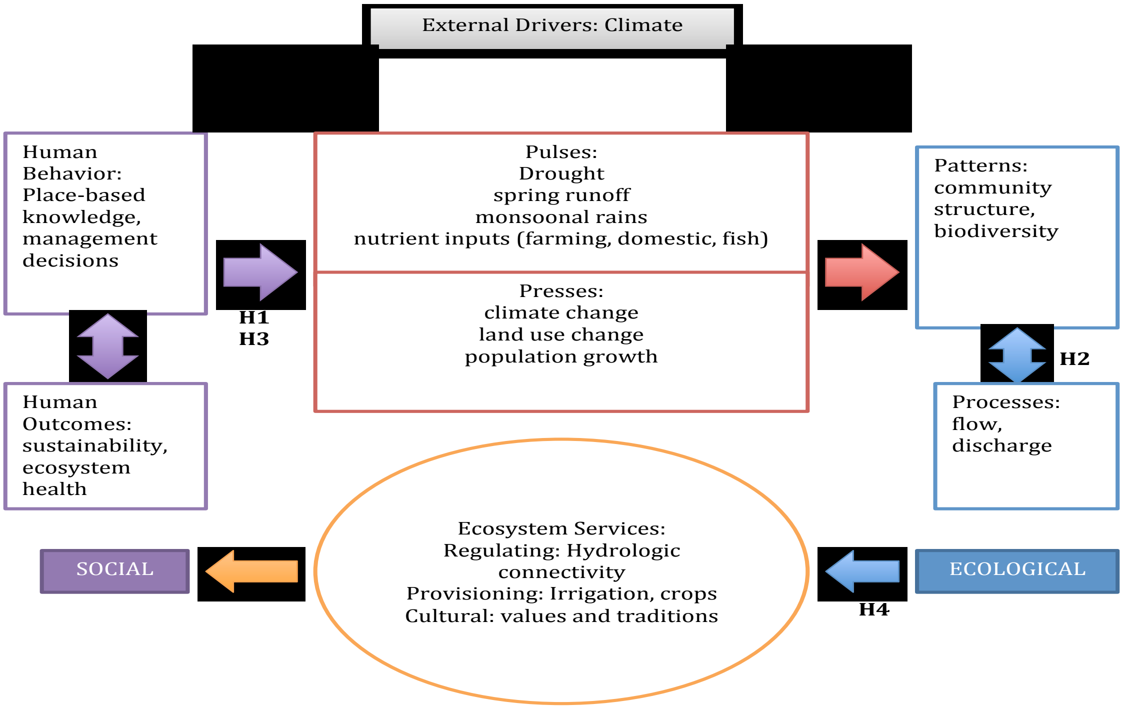

Figure 1. PPD framework for social-ecological research on the ecology of the acequias in the Mora Valley. *For clarity, only those components in our study are listed. Additional components could be added that would fit within the overall framework. Hypotheses (indicated H1-4 on the figure) are those listed in Table 1.*

STUDY SYSTEM: THE ACEQUIAS IN THE MORA VALLEY

The Mora River flows through Mora County in northern New Mexico. It begins life as a small trickle high in the Sangre de Cristo Mountains and ends its journey where it becomes a tributary of the Canadian River. To understand the hydrology of the Mora River, we first need to look at the geomorphology of the terrain through which it flows. Mora County is a max relief county, meaning that its relief is not only the greatest in New Mexico, but also ranks fifteenth of counties throughout the United States (Brekhus 2011). The difference between the county's highest point, Truchas Peak, at 3994 meters and its lowest point along the Canadian River at 1420 meters is 2573 meters. The headwaters of the Mora River are above 3660 meters and it is over 160 kilometers from headwaters to discharge into the Canadian River. The river flows from west to east and the slope is considerable, at least at first. The mountain terrain gives way to flat open plains soon after the river runs through the gauge at La Cueva, a few miles downstream from the village of Mora, and about half way through the river's length. The total drainage area is 44, 806 hectares.

Along most of its length, the waters of the Mora River are diverted into acequias, or irrigation ditches. At least forty-seven major acequias have been identified on the river. The longest of these is a trans-mountain acequia that carries water for more than 16 kilometers. The shortest is 0.8-kilometer (Kammer 1992). Most are used for irrigation of pastureland and hayfields, although some support what remains of subsistence farming in the valley (Martinez 1990). Water is supplied to the watershed via snowmelt and through summer rainstorms. The Mora is a snowmelt river, meaning that highest discharge occurs in late spring/early summer, although there is another spike in discharge during the “monsoon season”, generally late July through August. Groundwater and three trans-mountain acequias add a relatively small amount of water to the total water budget.

Flows on the Mora River are variable not only because of climate and weather, but also due to human influence. Each acequia is managed separate from the others, without regard to the natural flow of the river or the effects of management decisions made on other acequias. This results in the river at times going completely dry over a 3.4-kilometer stretch. At other times, flow in this area can be either greatly reduced, or near natural levels. The affected section begins just upstream of the village of Mora. Two major acequias, in close proximity to each other, divert water away from the river and over the floodplain. There are myriad smaller acequias that contribute to this connectivity between the longitudinal and lateral channels. Most of the water is not used and is redirected back into the river just downstream of the village. At the point where it returns to the river, flows are once again at natural levels, and the river appears healthy, with beaver and large fish in residence.

HYOPOTHESIS ONE: WATER RESOURCES HAVE BECOME LIMITED

Discussions about water in the Mora Valley eventually come around to stories of how much more precipitation the valley used to receive. Data from the Western Regional Climate Center’s stations at Chacon do not show this to be fact. There is even a statewide trend towards greater precipitation over the past half century (Table 2). If you look at the annual averages from the two operating stations in Chacon, between 1914 -1985 the yearly average precipitation was 50.01 centimeters and between 1985-2010 it was 56.54 centimeters. There are no data that support a sharp decline in precipitation. This may seem strange in light of the current short-term drought we are experiencing. 2011 was one of the ten driest in the state's history. When you take the current state of precipitation and combine it with increased water demand and the now accepted threat of climate change, it is easy to understand why this perception persists.

Table 2. *Thirty-year precipitation averages from the Chacon COOP stations and statewide in New Mexico. Note that these averages do not account for the current state of precipitation, nor do they show the considerable year-to year variability that is characteristic of the region. For example, the Chacon stations recorded a record low of 21.64 cm in 1956 and a record high of 89.26 cm in 1991.*

Dates for 30-yr averages	Precipitation (cm) at Chacon COOP	Precipitation (cm) for New Mexico
1931-1960	N/A	32.99
1941-1970	N/A	32.13
1951-1980	N/A	31.98
1961-1990	49.63	35.18
1971-2000	53.01	37.03
1981-2010	55.96	N/A

There is also a strong cultural component to the perception that water resources are limited. “El agua es vida”, or “Water is life”, is a saying you hear often in northern New Mexico. People are taught from a very young age that it is important to protect their water, and that early training leaves a very strong impression. Traditional acequia practices go hand in hand with cultural mores. Management of the acequias stays the same decade after decade, altered only when conditions warrant. Water is not particularly scarce in Mora, and many of the acequias in the valley run most of the year.

There is one way in which water has become more limited in the Mora Valley, and that is for domestic use. Although the county’s current population of just over 5600 has been greatly reduced from its high of 14,000 in the 1920’s, there has been a sharp increase in water demand as new people move into the area seeking vacation and retirement homes on former large ranches (Stephens 2005). So although water resources have not been depleted in the last century, these new demands for water, combined with climate change, could forever change the embarrassment of water riches in the Mora Valley.

HYPOTHSIS TWO: ACEQUIAS HAVE REDUCED FLOW ON THE MORA RIVER

In the village of Mora, people seeking relief from the summer’s heat by dipping their feet in the Mora River will often be disappointed. Current acequia management practices in the valley divert the water from the river into the acequias and leave the river mostly dry right in the center of town. The acequias extend the river’s channel beyond the riparian zone, and irrigate the valley's farmlands. At the lower end of town, water is redirected back into the river via acequia outlets, the sub-surface, or a multitude of culverts. Only several hundred meters after the first of these outflows, the river assumes the same appearance as above the diversion dam.

In the summer of 2009, we took flow measurements along a 27-kilometer stretch of the Mora River from the headwaters to below the affected stretch of the river. Using the Environmental Protection Agency's Environmental Monitoring and Assessment Program methodology (EMAP) (Peck *et al.* 2003), we recorded flow on June 9th and 10th, 2009 (Thomson and Ali 2009). At the headwaters, flow was 4.87 cubic feet per second (cfs). Within the affected stretch of the river, flow was 3.49 cfs, consistent with most of the water being diverted into the acequias, which we visually confirmed, and despite that fact that just below this stretch the flow was 38.78 cfs. This flow is about the same as we saw just upstream of the affected stretch, although we did not take measurements there. The huge difference in flow between the affected stretch and areas just upstream and downstream would not register on the gage at La Cueva, which showed a daily mean flow of 29 and 32 cfs on the dates of our study. These data are, however, consistent with our measurements, since additional water is diverted between our study sites and the gauge, a distance of several kilometers, and so slightly lower values would be expected.

In our study, flows on acequias were much less than those of the river. Measurements taken from acequias that did not divert significant water from the river ranged from 0.8 to 1.6 cfs. Where most of the river water was diverted, flows were much higher, and ranged from 5.92 to 14.44 cfs. These data are consistent with USGS data for La Sierra acequia recorded during the days of our study, when flow was 10-11 cfs. The lower flow within the acequias should have significant impact on the ecology of the river and these lateral extensions.

These data are not consistent with estimates of depletion for Mora County given in the Mora-San Miguel-Guadalupe Regional Water Plan (Stephens 2005). Those data show depletions of 15,234 acre feet and a return flow of 17,437 acre feet, or a loss of roughly half of the water being diverted for irrigation. This is clearly not the case in the western half the county, perhaps because of high precipitation, increased access to snowmelt, and a higher groundwater table.

HYPOTHESIS THREE: COMMUNITY PRACTICES HAVE INFLUENCE

New Mexico water law is complex, governed by multi-state laws, tribal law and federal law in addition to state law. As a subject, it is far outside the scope of this article. However, from an acequia perspective, what is important to note are that decisions regarding water rights are based on prior appropriation and beneficial use, or who was using it first and how they are using it. Article 16 of the New Mexico Constitution gives the state sole authority over water rights. Interestingly, however, the constitution does not actually define public welfare, and determining who had the water first can be tricky. The year 1907 is used to determine priority use, and the people in a given region have, for the most part, determined public welfare. Another important concept in acequia water law is adjudication, in which a lawsuit is begun on a given stream system to determine who owns what water rights (NMAA 2008). No acequias in the Mora Valley have been adjudicated and there are no plans to do so in the near future.

The Office of the State Engineer (OSE) has been tasked with water oversight and management decisions are based on the sixteen regional water plans. The regional plan for the Mora Valley includes all of Mora, San Miguel and Guadalupe counties. The data used to create this plan are problematic. Within the region, western Mora County and parts of western San Miguel County are ecologically different than the rest of the region, mainly due to different geomorphologies. In some instances, data collected in eastern Mora County can be almost the opposite of that collected in western Mora County and when combined, they cancel each other out. So management decisions made for the region may not always be appropriate for the Mora Valley. Another problem is that any decisions to be made under the current system take a very long time to be resolved. For this reason, decisions made locally by the acequias are often more important in terms of how water resources are managed.

Another way to look at the importance of community-based management decisions made by individual acequias is to compare them to other canal systems that have no direct community influence in their decision making. Here we compare the acequia system in the Mora Valley to the Central Arizona Phoenix Canal and the Salt River Project canals in Arizona. The most important physical difference between the three systems is scale. The Mora Valley acequia system is a small rural irrigation system serving local farmers. The Salt Valley Project canal system is a much larger, mixed rural and urban system that serves the people in and around the Phoenix metropolitan area. The Central Arizona Project aqueduct is a massive water transport system delivering

Colorado River water to the people of central Arizona. A short description of each system follows (Table 3).

The Central Arizona Project (CAP) was created by the Colorado River Basin Project Act of 1968 for the purpose of delivering Arizona's allocation of Colorado River water. The Central Arizona Water Conservation District, a municipal corporation, manages it. Along the length of the aqueduct are tunnels and pumping stations, as well as six recharge areas. These recharge areas divert water into shallow surface basins which drain into the ground to create "artificial groundwater". Although there are lateral extensions delivering water to end users, for the most part connectivity for the CAP is longitudinal and vertical.

The Salt River Project (SRP) canals are part of the Salt River Project, which consists of two organizations. The Salt River Project Agricultural Improvement and Power District, an Arizona state government entity, is an electrical utility created in 1936. The Salt River Valley Water User's Association, a private corporation, was created in 1903 to allow for dams to be built for the system and this corporation now delivers water to most of central Arizona. The eight main canals were built beginning in 1868, using impressions that remained of canals built by the Hohokam between 300-1450 A.D (Masse 1981; Roach *et al.* 2008). Beginning in 1947, the 131 miles of canals were lined with gunite to prevent erosion (Phillips *et al.* 2009).

The Mora Valley acequias were created for agricultural purposes by Hispanic settlers between the mid-1800's and early 1900's. The Mora Valley is about sixteen kilometers in length and the acequias run lateral to the main channel of the Mora River. Each acequia is managed by a mayordomo, or water boss, and three commissioners who are elected by the parcientes, or water users. Decisions are made collectively by the parcientes, and carried out by the mayordomo. In addition, each acequia operates independently. The acequias are physically unchanged from when they were built, with the exception of some concrete and metal replacing the traditional rock headgates. The ditches themselves are made from natural soils, mainly clay that are re-dug and manually cleared of vegetation and debris yearly. State law declares that acequias have the right to govern and manage themselves.

Table 3. *A summary of some of the characteristics of the three canal systems.*

	Mora Acequias	**Salt Valley Project**	**Central Arizona Project**
Length of main channel (km)	~20	211	541
Length of laterals (km)	~188*	2092	N/A
Acre-feet per year	33,000*	1.0×10^6	1.5×10^6
Main purpose	Agricultural	Direct agricultural (10%) and urban multi-use (90%)	Water transfer to municipal, agricultural and Native American water districts

Hydrological Connectivity	Longitudinal, lateral	Longitudinal, lateral	Longitudinal, vertical
Construction	Soil	Gunite	Cement
Management	Mayordomos (independent)	Salt Valley Water Users Association (private)	Central Arizona Water Conservation District (public)

*These numbers represent the Mora River over its entire length.

As noted in Table 3, the Mora Valley acequias function on a much smaller spatial scale than the SRP and CAP canals. The acequias are still being maintained by the parcientes, who adjust their practices immediately to compensate for any new demand on the system. The SRV and CAP management does not have this flexibility to react and make changes on a short time scale. The SRV, for example, still use irrigation system field operators to open and close headgates according to schedules that may no longer be effective or even necessary. Originally, most of the canal water was directly delivered to users, now almost all of it goes through water treatment plants and then automatically out to users. In addition, some canals that are no longer used are still being maintained. Management has not kept up with operations (Gooch *et al.* 2007).

This inability to make swift changes limits the effectiveness of the SRV, CAP, and New Mexico OSE management practices. Let’s examine this idea using short-term drought. Drought is a constant threat in all of these systems. In the Mora Valley, the mayordomo can see the effects of drought firsthand, and can instigate changes in operations to conserve water almost immediately. He may need to meet with other acequias to come to an agreement on how to share the water, but that can be handled quickly. The time scale for operational changes for the other three systems is so slow that by the time the changes are made in operations, it could be too late. The response of the SRV management to the long-term reduction in available water, for example, has been to purchase excess water from CAP when it is available (Phillips *et al.* 2009). What will happen if we continue to see reductions in available water due to climate change? SRV projections predict that overall runoff will be reduced by 20-50 percent in the next fifty years. There is no other plan in place in the event that CAP does not have excess water available for purchase. The lack of response of the SRV to Phoenix becoming an urban heat island is another example. Even though there is evidence that the overall temperature in Phoenix has increased 7.5° C above that of the surrounding area and CO_2 levels are double that of the global average, management has not addressed what changes in operations should be made in response to these environmental changes (Shen *et al.* 2009). CAP and OSE management also have no plans in place to deal with climate change. Yet acequias have already been adjusting to climate shifts in some places for several hundred years.

HYPOTHESIS FOUR: COMMUNITY PRACTICES PROTECT THE ECOSYSTEM

As noted, the headwaters of the Mora River are in the Sangre de Cristo Mountains, which are the southernmost portion of the Rockies. Vegetation is mostly subalpine forest. As the river moves down into the Mora Valley, the vegetation gives way to ponderosa pine forest and non-native vegetation such as hay pastures. Gross primary production is dominated by allochthonous material throughout the length of the river, although autochthonous production increases in the main river channel down on the flat open plains. An abundance of algae in the acequias suggests they play a major role in the production of autochthonous material within the lateral extensions of the river system.

The Mora River is designated a high quality cold water fishery in its upper reaches, and a cold water/warm water fishery from the affected stretch until it flows into the Canadian River. Trout, native and introduced species, inhabit the upper reaches, and additional fish species also live in the river. It is not known whether fish inhabit the acequias as residents, but they are often present in the waters of even the smallest acequias, perhaps as unfortunate visitors. When there is no flow in the affected stretch of the river, pools that remain get warmer and deoxygenated as they evaporate, and many fish and other organisms die between wet flow periods and dry periods. It is unknown how this affects fish, algae and macroinvertebrate populations in the stream outside of the affected area. There also is no upstream migration, nutrient spiraling, or downstream drift of any aquatic organisms when the river is dry. The patchy nature of the acequias disrupts the simple upstream-downstream production model we should expect from the Mora River and makes assumptions based on current theoretical models about stream structure and function problematic.

We conducted macroinvertebrate sampling at three sites along the Mora River in June 2009 using a kick net and field identification. One site was above the dry stretch and two were below it. Our results showed an abundance of insect orders that are intolerant of pollution. Groups fairly to very tolerant of pollution were also present at all sampling sites, but in lower numbers (Thomson and Ali 2009). Using a Pollution Tolerance Index developed by Hoosier Riverwatch (2009), all three sites were given ratings of excellent with scores of 24, 37, and 36. Anything over 22 defines a reach as excellent, meaning the river is in good condition at our sampling sites. A more rigorous study looking at macroinvertebrate community structure between and within the river and acequias is currently underway, and based on preliminary unpublished data, there are more differences than this short study shows.

In addition, we took water samples for five sites on the Mora River and seventeen on acequias/tributaries. A total of nine of those sites were used in the results/analysis for this paper. We measured pH, temperature, dissolved oxygen, electrical conductivity, flow volume and alkalinity in the field. Analyses were conducted at the University of New Mexico's Environmental Analysis Laboratory in the Earth and Planetary Science Department (Thomson and Ali 2009). Of these data, three river sites and three acequias were evaluated for water quality (Table 5). As expected, pH showed little variation. Temperature was within expected limits and mostly followed a predictable elevation gradient. Dissolved oxygen was always within limits, and often reached saturation. In most cases, electrical conductivity was slightly higher than the recommend level, and showed a clear increase as we moved downstream. As conductivity is often used to estimate total dissolved solids (TDS), this suggests that non-point source pollution is occurring along the river. Nutrient analyses were completed for the three river sites and four acequias (Table 4). Overall parameters were within TMDL limits established by the NMED for the Mora River, although phosphorus and total nitrogen in some cases came close or were slightly above the limits (Table 6). This was especially true in acequias. A complete analysis of all water samples can be found in Thomson and Ali (2009).

Table 4. Sampling sites from June 2009 used for this paper.

Site	Hydrology	Water Quality	Nutrient Analysis	Macro-Invertebrates
Luna Creek (Headwaters)	X	X	X	X
Mora River @ Allsups	X	X	X	
Mora River @ Romero Ranch	X	X	X	X
Mora River @ Wind River Ranch				X
Acequia @ Chacon turnoff	X			
Lower Acequia-Mora Research Center	X	X	X	
Upper Acequia-Mora Research Center	X	X	X	
Acequia @ CR A002	X			
Trambley Acequia	X	X	X	
El Carmel Acequia	X			
Acequia @ Fish Hatchery	X		X	

Table 5. Summary of water quality measures on the Mora River and acequias in the Mora Valley, June 2009. *Three sites on the Mora River and three acequias were sampled. Not all data were collect for all acequias; the number in parentheses indicts how many were measured. See Table 4 for details. DO (mg/L) = dissolved oxygen in milligrams per liter, EC (µS/cm) = electrical conductivity, Temp (°C) = temperature in degrees Celsius*

	pH	**DO (mg/L)**	**EC (µS/cm)**	**Temp (°C)**
Mora River	7.21 - 8.95	8.5 - 11.23	247 – 490	7.8 - 15.3
Acequias	7.84 (1)	13.0 - 13.6 (2)	172 - 516 (3)	9.7 - 15.9 (3)

Table 6. Summary of nutrient analysis for the Mora River and acequias in the Mora Valley, June 2009. *The same three sites on the Mora River were sampled. Four acequias were sampled; only two were the same as in Table 5. See Table 4 for further details. Total Maximum Daily Load (TMDL) limits for the Mora Rover are 0.38 mg/L for combined nitrate and ammonium (total nitrogen) and 0.03 mg/L for phosphorus (in this case SRP phosphate).*

	Nitrate (mg/L)	**Ammonia (mg/L)**	**Total Nitrogen (mg/L)**	**Phosphate (mg/L)**
Mora River	0.09 - 0.13	0.12 - 0.25	0.21 - 0.38	0 - 0.02
Acequias	0.1 - 0.69	0.03 - 0.45	0.13 - 1.14	0 - 0.04
TMDL limits	--	--	0.38	0.03

CONCLUSIONS

While further investigation is needed to conclusively state exactly how community-based and governmental management practices are affecting the ecology of the Mora River and its acequias, we suggest that given the current situation, both are instrumental in sustaining ecological health, effective irrigation and supporting cultural traditions and place-based knowledge. Acequia management practices should be integrated into regional water plans as they can quickly compensate for both pulse and press events.

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LITERATURE CITED

Brekhus, J. 2011. Maximum Relief Counties by State. http://www.cohp.org/records/relief/Helman_counties.html

Central Arizona Project (CAP) website. 2011. http://www.cap-az.com/

Collins, S.L., S.R. Carpenter, S.M. Swinton, D.E. Orenstein, D.L. Childers, T.L. Gragson, N.B. Grimm, J.M. Grove, S.L. Harlan, J.P. Kaye, A.K. Knapp, G.P. Kofinas, J.J. Magnuson, W.H. McDowell, J.M. Melack, L.A. Ogden, G.P. Robertson, M.D. Smith, and A.C. Whitmer. 2011. An integrated conceptual framework for long-term social ecological research. Frontiers in Ecology and the Environment 9 (6): 352-357.

Cox, M., and J.M. Ross. 2010. Robustness and vulnerability of community irrigation systems: The case of the Taos valley acequias. Journal of Environmental Economics and Management 6 (2011): 254-266.

Cox, M. 2008. Applying a social-ecological system framework to the study of the Taos valley irrigation system. Workshop in Political Theory and Policy Analysis, Indiana University, Bloomington.

DeBuys, W. 1985. Enchantment and Exploitation: The Life and Hard Times of a New Mexico Mountain Range. University of New Mexico Press, Albuquerque.

Fernald, A.G., Baker, T.T. and S.J. Guldan. 2007. Hydrologic, riparian, and agroecosystem functions of traditional acequia irrigation systems. Journal of Sustainable Agriculture 30 (2): 147-171.

Fernald, A.G. and S.J. Guldan. 2006. Surface water-groundwater interactions between irrigation ditches, alluvial aquifers, and streams. Research in Fisheries Science 14:79-89.

Gooch, R.S., P.A. Cherrington, and Y. Reinink. 2007. Salt River Project experience in conversion from agriculture to urban water use. Irrigation and Drainage Systems 21:145–157.

Hoosier Riverwatch. 2009. http://www.in.gov/dnr/nrec/files/nc-Riverwatch_Manual.pdf

Kammer, D. 1992. Report on the Historic Acequia System of the Upper Rio Mora. New Mexico Historic Presentation Division.

Martinez, F.J. 1990. Mora- San Miguel Regional Water Study and Forty Year Plan. Office of the State Engineer, Santa Fe, New Mexico.

Masse, W.B. 1981. Prehistoric Irrigation Systems in the Salt River Valley, Arizona. Science 214 (4519): 408-415.

New Mexico Acequia Association (NMAA). 2008. Acequia Governance Handbook. www.lasacequias.org

New Mexico EPSCoR. 2011. Acequia Research Impacts. http://nmepscor.org/content/acequia-research-impacts

Peck, D.V., Lazorchak, J.M., and D.J. Klemm (Eds.). 2003. Western Pilot Study: Field Operations Manual for Wadeable Streams (DRAFT). United States Environmental Protection Agency Office of Research and Development, Washington, D.C.

Phillips, D.H., Y. Reinink, T. E. Skarupa, C. E. Ester III and J. A. Skindlov. 2009. Water resources planning and management at the Salt River Project, Arizona, USA. Irrigation and Drainage Systems 23:109–124.

Rivera, J.A. 1998. Acequia Culture: Water, Land and Community in the Southwest. University of New Mexico Press, Albuquerque.

Roach, W.J., J.B. Heffernen, N.B. Grimm, J. R. Arrowsmith, C. Eisinger, and T. Rychener. 2008. Unintended consequences of urbanization for aquatic ecosystems: A case study from the Arizona Desert. Bioscience 58 (8): 715-727.

Rodriguez, S. 2006. Acequia: Water Sharing, Sanctity and Place. School from Advanced Research Press, Santa Fe, New Mexico.

Roybal, M. 2012. Measuring acequia functionality: Developing a tool for assessing New Mexico’s community based irrigation systems. Unpublished Professional Project. University of New Mexico, Albuquerque. 123 pp.

Salt River Project (SRP) website 2011. http://www.srpnet.com

Shen, W., J. Wu, N. B. Grimm, and D. Hope. 2008. Effects of Urbanization-Induced Environmental Changes on Ecosystem Functioning in the Phoenix Metropolitan Region, USA. Ecosystems 11: 138–155.

Stephens, D.B. and Associates, Inc. 2005. Mora-San Miguel-Guadalupe Regional Water Plan. http://ose.state.nm/isc_regional_plans8.html

Thomson, B. and A-M. Ali. 2009. Water resources assessment of the Mora River. http://hdl.handle.net/1928/9704

United States Department of Agriculture (USDA). 2007. Census of Agriculture: Volume 1: Chapter 2, County Level Data / New Mexico. http://www.agcensus.usda.gov/Publications/2007/Full_Report/Volume_1,_Chapter_2_County_Level/New_Mexico/

United States Geological Survey (USGS). 2012. Water Science for Schools.

http://ga.water.usgu.gov/edu/wetstates.html

United States Geological Survey (USGS). 2009. USGS Real-Time Water Data for USA.

http://waterdata.usgs.gov/nwis/rt

Western Regional Climate Center (WRCC). 2012. http://www.wrcc.dri.edu

Addendum to the paper ACEQUIA CULTURE BENEFITS ECOSYSTEM FUNCTION, published December 2012 in the New Mexico Journal of Science:

ACEQUIA CULTURE MAY AMELIORATE THE EARLY EFFECTS OF CLIMATE CHANGE THROUGH HUMAN RESPONSE TO ITS IMPACTS

Climate change is no longer a debate; it is a given. And while climate change was not within the scope of my original research proposal it is, by its very existence, a factor in my work. It is important because small headwater streams will be the first waterways to respond to the effects of climate change and the small mountainous watersheds that contain these streams are perhaps the hardest ones to study in terms of data gathering (Carpenter *et al.* 1992). In addition, conservative estimates show that headwater streams account for more than 70% of stream length in the United States (Lowe and Likens 2005). While these small streams may not have as great an impact as larger streams to the landscape or to people overall, they have the potential to teach us important lessons that can be applied to larger streams. The Mora River is also of interest in that it has both natural and managed components, and could prove a valuable model for human response to changes caused by climate.

Bales *et al.* (2005) argue that the complex ecology and topography of mountain regions coupled with their steep and variable temperature and precipitation gradients make it difficult to get a complete picture of processes in a headwaters stream. They argue in particular that water fluxes into and out of a mountain system need more directly networked measurements and that inferring the processes of an entire watershed based on spotty point scale measurements may fail to capture what is truly happening in these systems. The authors do not argue against modeling and remote sensing, but insist that better *in situ* measurements are needed for a complete picture. In addition, the small size of mountain watersheds means that these streams are more intimately coupled to the terrestrial environment (Lowe and Likens 2005). Unlike larger streams, which may or may not be affected by the landscape beyond the riparian zone, headwater streams are greatly influenced by the landscape's upslope processes, including deposition of organic materials, soil erosion and other natural and anthropogenic perturbations. (I use the term perturbation to mean a temporary move away from steady state, as opposed to a disturbance, which resets the ecosystem to a new steady state. A disturbance would affect both large and small streams to the same degree.) It also means that data gathering methods used at larger spatial scales and at lower elevations, where topography and climate gradients are more consistent, do not always work in mountain streams. It is, for example, much harder to get an accurate measure of snowfall as precipitation in a small watershed than in a larger one. Add to this the complications involved in characterizing weather and water cycles in mountainous watersheds and the result is a dearth of data. Few multi-decadal data sets are available and *in situ* data are seldom sufficient (Gutzler and Keller 2012).

One thing very evident from my study is that simply gauging a river does not tell its story. If you look at the Mora River only at two places: at Holman (before it goes dry from being diverted into the Mora Valley acequias) and at La Cueva (downstream of the valley's diversions), those sites will not give you the entire picture of what is happening on the river. The data are limited, but if you compare discharge data from the no longer operational U.S.G.S. gauge at Holman (07214500) to that of the gauge at La Cueva (072145500) you can see this for the years 1954-1957. These are the only years where complete data are available for the Holman site (Table A.1).

Table A.1. Discharge at two U.S.G.S. gauges on the Mora River. *Holman is upstream of where the Mora River is usually dry, and La Cueva is downstream. Average drainage per unit area was almost double at Holman, demonstrating the importance of runoff in the upper part of the watershed.*

Water Year	**Discharge at Holman (cfs) with drainage area of 14,763 hectares (57 mile^2)**	**Discharge per unit area (cfs/mile^2)**	**Discharge at La Cueva (cfs) with drainage area of 44,807 hectares (174 mile^2)**	**Discharge per unit area (cfs/mile^2)**
1954	3.70	0.065	5.56	0.032
1955	7.09	0.124	18.1	0.104
1956	2.72	0.048	3.12	0.018
1957	16.4	0.288	28.8	0.166

Two things are evident in this dataset. One, it appears that runoff is of greater importance in the upper part of the watershed as there is almost double the runoff there than in the lower part of the watershed. However, it could also be that the lower discharge per area for the downstream gauge could be the result of irrigation in the valley. This argues again for more *in situ* measurements on the watershed. The second thing evident in this small dataset is that these two measurements suggest a continuous flow along the Mora Valley, and give no indication of the complexity of what is actually happening. Without further information, there would be no way to know that: 1) the river between these two gauges is dry for most of the year, and 2) that a myriad of acequias branch off and return to the river along the way. Without this place-based knowledge, scientists and policy makers who have no personal knowledge of the area could misinterpret data, and decisions that they make could lead to increased problems and potential long-term damage to the ecosystem.

What are the predicted effects of climate change in northern New Mexico? In particular, how will these changes affect headwater streams? What changes, if any, can we make in our management of acequias that will ameliorate the effects of climate change? These are the three questions we will look at in the remainder of this paper.

Current models are consistent on temperature. It will get hotter over the next fifty to one hundred years, between 3.3 - 6.7 °C , depending on the projection (Gutzler 2013, New Mexico 2005). This increase in temperature will be more pronounced at higher elevations and in the winter, and over time will result in reduced snowpack and earlier spring runoff. This change in both the timing and storage of winter water means decreased spring soil moisture as well, particularly if precipitation declines.

Models are mixed on future precipitation trends. There may be more, or less, or overall precipitation amounts can remain unchanged. Regardless of this, because of the increase in temperature, more precipitation will fall as rain, rather than snow, which will reduce stored water capacity. Finally, most models predict a continuation of the historical wet and dry cycle variability that characterizes weather in northern New Mexico, along with the more extreme weather events predicted at the global scale. Overall, the models predict that weather in northern New Mexico will be warmer and more extreme in its variability. See Figure A.1 for a graphic summary of these predicted outcomes.

Climate change as predicted will disrupt both the timing and the storage of water in small headwater streams. This will be particularly important in snow-fed streams, such as the ones that sustain the Mora River and most smaller streams in the Sangre de Cristo Mountains, because these headwater streams will be the first to feel the effects of climate change (Carpenter *et al*. 1992, Durance and Ormerod 2007, Harding 2010, Lowe and Likens 2005). Let's assume for this discussion that the predicted temperature increase occurs. This would result in less snowpack and earlier melt of the snow that does accumulate in the winter. The predicted melt would result in high runoff 3-4 weeks earlier that what we currently experience (Rango and Rivera 2012, personal communication). In a perfect scenario, the melt would occur just at the beginning of the frost-free period. The runoff will then sustain local landscapes until the monsoon season.

Some years the timing is good, sometimes it isn't. But if it is not good consistently, and farmers do not have the ability to sustain a crop until the monsoon, the result would be a critical lack of water during the time it is most needed. If you add to this the idea that there is less snow overall (as more precipitation falls as rain throughout the year, you compound the problem with a lack of stored water. Currently, extra snowmelt (as well as extra water during the monsoon season) as stored in small manmade shallow earthen basins called tanques. Most are connected to acequias to divert this runoff, but if there is no extra snowmelt, only the monsoonal rains will be available for storage, and again they may come too late to sustain the land.

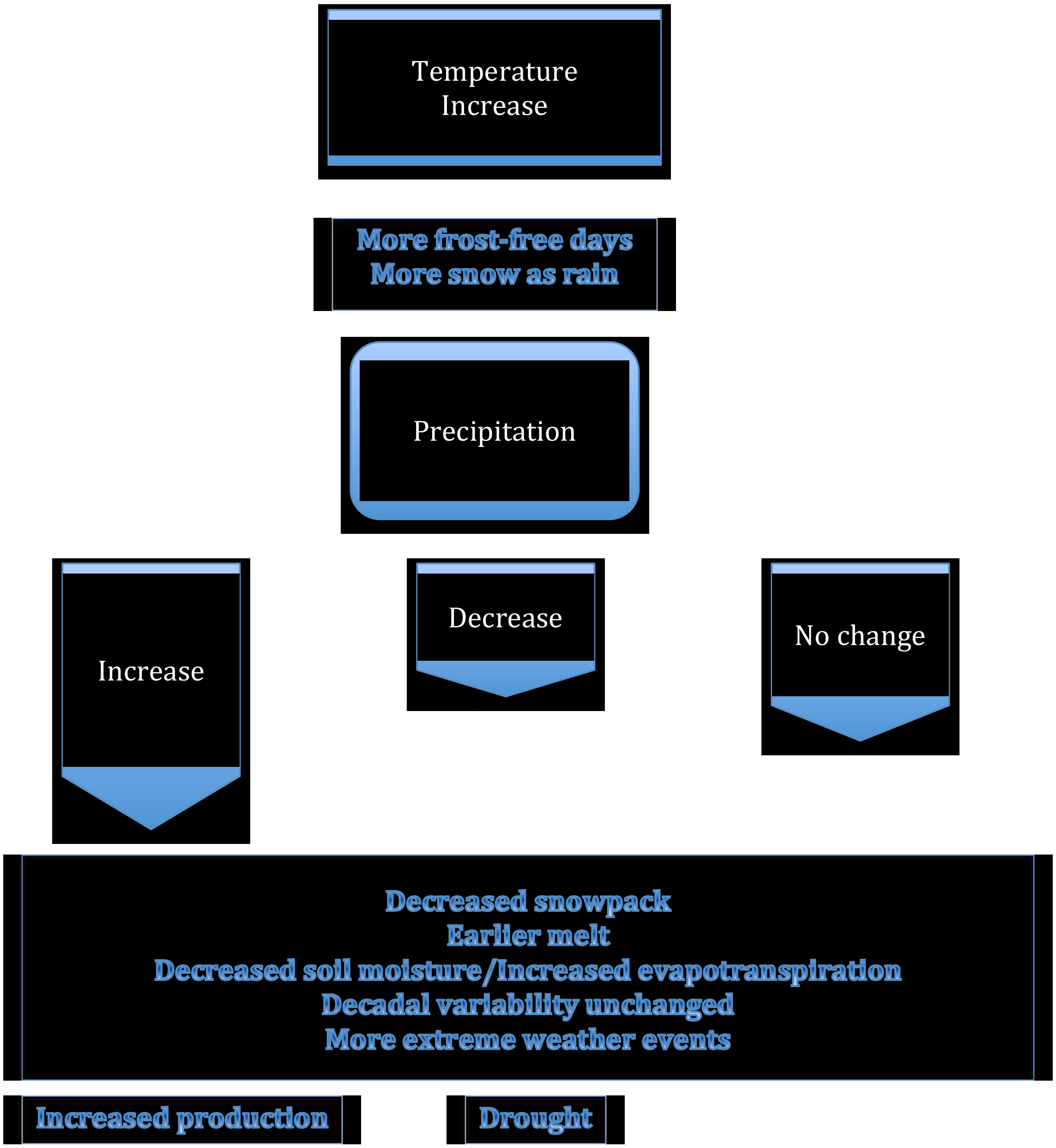

Figure A.1. Possible effects of predicated climate change in northern New Mexico. *While all models agree that there will be an increase in temperature, models are mixed on precipitation, which could increase, decrease or remain the same. Beneficial responses from acequia culture to these effects, summarized in the blue boxes, are discussed in the paper.*

There is evidence to suggest that timing will not be as critical for streams that are being managed (Brickey et al. 2010). The good news for the Mora River and its basin is that cultural traditions and place-based knowledge have not been lost throughout most of northern New Mexico and the decadal variation that the people have long been used to will work to their advantage to ameliorate the early effects of climate change. The *mayordomos* and other water managers in these rural areas have dealt with multi-year drought and wet periods and understand what needs to be done to take advantage of the season's weather. For example, in years without water, they share, find other pasture for animals, even reduce their herds. In years when water is abundant, pastures are restored, tanques are filled and flushed, and hay is harvested. The same is true for the streams and acequias. Restoration of bank erosion that can occur during dry periods is stabilized by vegetative growth when water is abundant. Studies have shown that biodiversity in semi-arid and mountainous streams also recovers during times of abundant water. For now, there are feedbacks in place that reduce the detrimental effects of these decadal variations in timing and storage.

But what happens when we go beyond the variations that we now experience? What happens when extreme weather events disrupt this cycle? What happens when water is no longer ever abundant? That is when we will have problems. Adjusting for timing and storage will no longer be effective. Agriculture will be reduced by one-third, according to most estimates (D'Antonio 2006, Hurd and Coonrod undated). This will also have a significant impact on the life histories of aquatic macroinvertebrates in these streams as well (Carpenter, et al. 1992, D'Antonio 2006, Durance and Ormerod 2007). Both are significant.

Table A.2. Predicted effects of climate change due to increased temperatures, regardless of changes in overall precipitation. *These effects have consequences in terms of both timing and storage of water in both streams and the acequias in the Mora Valley.*

Predicted effect	**Consequences to timing**	**Consequences to storage**
More frost-free days	Yes	No
More precipitation falling as rain	Yes	Yes
Decreased snowpack	Yes	Yes
Earlier spring runoff	Yes	Yes
Decreased soil moisture/Increased evapotranspiration	No	Yes
More extreme weather events	Yes	Yes
Unchanged decadal variation	No	No

So let's address these predicted changes one at a time. We will assume the increase in temperature for all situations. How will these changes affect the timing and storage of water in the Mora Valley? How can/does acequia culture mitigate these changes?

MORE FROST FREE DAYS

As I write this from my home above the Mora Valley in the winter of 2015, I am acutely aware of the current effects of climate change, not only from what I hear on the television every night—record breaking snow and cold on the east coast and south, while people are already starting gardens in February on the west coast—but from what is happening in my own back yard. While this winter has seen more snow than in the past eight years, no one mentions that for the first time since I have lived here, the ground did not freeze solid all winter. I understand that we can't call weather climate change over such a short period of time, but any way you look at it, the ground not freezing at 8500 feet in the Rocky Mountains is odd. We intuitively understand that this must be a result of a very warm winter, but it is more challenging to think of the consequences of more frost-free days. It would seem at first a good thing—a longer growing season and earlier use of spring runoff for irrigation—but the impact on water resources will be that there will be less water overall due to the warming of the climate. Growing plants would start earlier in the season to take advantage of spring runoff and the earlier end to killing frosts. There is even a prediction for higher crop yields at high elevations in New Mexico.

The Mora Valley acequias differ from most other acequia systems in that they are not water limited under current environmental conditions. Warming could result in summer shortages and even a complete lack of water. Currently the river is experiencing some of its lowest discharge rates, and yet most of the acequias have water flowing year round. The significant snow this winter means that for this summer at least this trend will continue. The people in the Mora Valley are lucky. Those who are less able to adapt will feel climate change more. For now, the valley has two things going for it: 1) water is still adequate, and 2) while most of the population still irrigate their fields, few rely on their farming to support themselves. I believe it will be cultural tradition that will push the people in Mora to adjust to changing climate, and not necessity.

MORE PRECIPITATION FALLING AS RAIN

Another consequence of this winter's non-frozen ground is mud, and the ability of the snow and rain to be absorbed into the ground. So for a while, at least at this elevation, storage will shift from snowpack to the ground, resulting in a shorter time for storage of winter precipitation. Again, at first this may even have a beneficial effect in the high mountains and in headwater streams, but eventually, it will result in a shorter storage period of what water is in the watershed. It will also increase local spring flooding in the Mora River. Diverting floodwaters into acequias can marginally control flooding, but this means that even before water becomes scarce, it will no longer benefit the ecosystem but will be removed too quickly.

DECREASED SNOWPACK

To quote David Attenborough in the BBC Earth series Frozen Planet (2012): "Each snowflake is water waiting to be released in spring". While this may sound overdramatic snowpack is, in effect, stored water in northern New Mexico. This is important because the only water available in springtime is from stored water, as spring rains are not common and are limited when they do occur. It is the snowpack that nourishes the soil and new spring growth and on a good year is sufficient to maintain vegetation until the monsoonal rains arrive in mid-summer. So less snowpack and an earlier melting of that reduced snowpack will have significant impact on soil moisture and plant growth in northern New Mexico, particularly in dryer years, in terms of both storage and timing. Less snowpack means the water will be available for a shorter period of time and there will be less of it. An earlier melt means the period of time this water is available will be a predicted 3-4 weeks earlier than we see now.

EARLIER SPRING RUNOFF

Both decreased snowpack and earlier spring runoff will impact agriculture and create a situation where downstream water users in a headwaters stream will want to "spend early" and use the water as it is available. New Mexico state law does not allow upstream water users to store runoff in times of water shortages, so this will encourage increased diversion of water into tanques earlier in spring, resulting in water downstream becomes less available earlier in the season.

DECREASED SOIL MOISTURE/INCREASED EVAPOTRANSPIRATION

People who discount climate change often say that since an increase in global temperature will result in an increase in plant growth, and since plants use carbon dioxide and release oxygen, this will be a good thing. And to a degree, they are correct. We will see increased plant growth with higher temperatures, but only as long as plants have the resources they need to grow. Warmer temperatures will result in less soil moisture, which in turn will result in soil erosion as a result of water loss, water degradation as less fresh water moved through the systems, more pests and invasive species, and in unmanaged areas, changes in plant composition (D'Antonio 2006). Acequia culture will respond by revising planting/harvesting schedules, using different tillage methods and switching crops. We have seen this in the past, when the valley suffered extreme environmental degradation due to overuse for cash crops to sell to Fort Union. It was only after the fort closed that farmers in Mora County shifted to the current hay crop, and allowed the land to heal.

MORE EXTREME WEATHER EVENTS

We are already seeing, on a global scale, the extreme weather events predicted by climate change. And while there has been episodic drought and flooding in the Mora Valley, it has, up to this point, been more directly related to decadal variation and not climate change. Land use, most notably overuse, has had a greater impact on the environment in the past than weather events. Still, there have been droughts and floods and in most cases, acequia culture has been able to lessen the damaging effects.

Brickey *et al.* (2010) suggest that with increased drought due to climate change, more flexible water rights should be considered. In acequia culture, sharing of water during times of drought is known as "repartimiento". Communities come together to plan the most effective way for all water users to get what water they need. This cooperative, informal way of sharing water in times of drought will no doubt influence the success of how acequia water is managed as climate change effects water use on a long time scale.

Climate change will also lead to increased flooding. Floods have two main effects: damage to stream banks and floodplains, and a loss of unused water. Reservoirs fill early and are used earlier, so water in floods is often “wasted” water that is available when it is not needed, and disappears before it can be used. In a managed system where acequias diverge this floodwater, less damage occurs. While there is really no way to save the water for when it is needed, at least acequia culture controls floodwater to some degree.

UNCHANGED DECADAL VARIATION

New Mexico has strong decadal variation in its weather. A decade long drought followed by several years of really wet weather is common in the Mora Valley. Acequia culture passes on protocols of how to deal with this conditions from generation to generation in the irrigation associations that are formed for every active acequia. From parent to child and neighbor to neighbor, these things are taught and the decadal variation is accepted as just part of life in Mora.

SUMMARY

So what will be the outcome of these changes? What will be the consequences and what will be the response from acequia culture? How will local acequias respond to these changes? In addition, what can we learn from acequia practices that could be used by water managers in larger system downstream in their response to these changes? The Mora Valley acequias are not as old as other acequias in northern New Mexico; some have been operational for centuries. Yet even with no other evidence than their continued operation and their longevity, it is apparent that acequia culture is resilience and has the ability to respond to perturbations in a natural system through management of water.

Surprises, however, will be inevitable with climate change, because ecosystem changes are predicted to no longer happen gradually over time, but instead will be rather abrupt due to positive feedback. We know that acequias can moderate perturbations if a change happens over time (see Chapter 2). With climate change causing abrupt changes, human response time will need to be faster than in the past. As I demonstrated in the first published part of this chapter, the more complex the water organization, the longer the time before response to change. It may benefit all of us to study how acequia managers moderate these early changes and apply that knowledge on a larger and faster scale. We may not have the luxury of taking our time to respond to what may be a critical situation. An earlier worldwide response to global warming may have slowed the effects with which we are now confronted. An earlier response to the predicted outcomes of climate change may also slow the effects. But we need to address this now, and not in retrospect.

Table A.3. *Beneficial response from acequia culture to the effects of climate change.*

Possible effect of climate change	**Possible beneficial response from acequia culture**
More frost free days	Ability to shift planting/harvesting schedules, change crops and tillage methods
More precipitation falling as rain	Store water went plentiful
Less snowpack	Water sharing "repartimiento"
Earlier snowmelt/spring runoff	Adjust timing of water use
Less soil moisture/increased evapotranspiration	Adjust land use
Flooding	Diversion into acequias reduces damage
Drought	Water sharing "repartimiento"
Unchanged decadal variability	Cultural understanding of this variation and how to respond to it

LITERATURE CITED

BBC Worldwide Ltd. 2012. Frozen Planet, The Original UK Series, Narrated by David Attenborough. www.bbcearth.com

Bales, R.C., Molotch, N.P., Painter, T.H., Dettinger, M.D, Rice, R., and J. Dozier. 2005. Mountain Hydrology of the Western United States. http://fiesta.bren.ucsb.edu/~dozier/REASoN-pubs/2005WR004387.pdf

Brickey, C., K. Engel, M.L. Miller, K. Jacobs, D.F. Lueke and B. Udall. 2010. How to Take Climate Change Into Account: A Guidance Document for Judges Adjudicating Water Disputes. Arizona Legal Studies Discussion Paper #10-47. University of Arizona James E. Rogers College of Law.

Carpenter, S.R., Fisher, S.G., Grimm, N.B. and J.F. Kitchell. 1992. Global Change and Freshwater Ecosystems. Annual Review of Ecology and Systematics 23: 119-139.

D'Antonio, J.R. 2006. The impact of climate change on New Mexico's water supply and ability to manage water resources. New Mexico Office of State Engineer, Santa Fe, New Mexico. www.nmdrought.state.nm.us/ClimateChangeImpacy/completeREPORTfinal.pdf

Durance, I. and S.J. Ormerod. 2007. Climate change effects on upland stream macroinvertebrates over a 25-year period. Global Change Biology 13:942-957.

Gutzler, D.S. 2013. Regional climatic considerations for borderlands sustainability. Ecosphere 4(1):7.

Gutzler, D.S. and S.J. Keller. 2012. Observed trends in snowpack and spring season soil moisture affecting New Mexico. New Mexico Journal of Science. 46, pp.

Harding, J.J. 2010. Linking mountains and valleys: exploring the influence of mountain hydrology on traditional acequia irrigation systems. Paper No. 37-1. Geological Society of America Abstracts with Programs, Vol. 42, No. 5, p.111.

Hurd, B.H. and J. Coonrod. Undated. Climate change risks New Mexico's waterways, its byways and its flyways. Water Resources IMPACT 10:4.

Lowe, W.H. and G.E. Likens. 2005. Moving headwater streams to the head of the class. BioScience 55:3, pp 196-197.

New Mexico Agency Technical Work Group. 2005. Potential effects of climate change on New Mexico.
http://www.nmenv.state.nm.us/aqb/Potential_Effects_Climate_Change.html.

Rango, A. and J. Rivera. 2012. Personal communication.

Chapter Two

LAND USE CHANGE IN THE MORA VALLEY OF NEW MEXICO

Shannon M. Rupert and Lisa Majkowski

ABSTRACT

Agricultural land use in northern New Mexico is often represented as slowly changing from sustainable, subsistence practices to environmental degradation. The truth is that human impact has always been substantial in riparian areas along waterways. In the Mora Valley, this impact was most evident in the first fifty years after settlement, and reached its peak within one hundred years. In the century since that time, the land has recovered and land use has become remarkably stable. This study used aerial orthophotographs and GIS techniques to compare historical agricultural land use to modern use of the valley's rich farmlands. While tree cover on the valley's slopes has increased, use of the valley's farmland has remained relatively unchanged over the past seven decades. Since the mid-20th century, most fields have produced alfalfa or livestock. In addition, we used GPS to map the major acequias in the valley to order to test whether we could map the acequias using aerial photographs and GIS techniques only. It is possible to map the acequias with a high degree of accuracy without ground-truthing them, as our digital mapping and ground-truthing matched almost seamlessly. This should prove a valuable technique for communities who would like to map their acequias but have limited resources. Very little change has occurred in acequia location and riparian zones in the Mora Valley since the 1950's.

INTRODUCTION

The agricultural history of the Mora Valley in northern New Mexico is one of rapid change followed by long-term stability. This is contrary to what we have come to think of as the history of agriculture in northern New Mexico. We are used to hearing of how the original Pueblo peoples and the early Spanish settlers lived a sustainable existence as hunter/gatherers and farmers. While this story of sustainable living is not altogether true, the rate of environmental degradation was much lower before the arrival of the Spanish in the late sixteenth century and again before the arrival of Anglo settlers late in the mid-nineteenth century. Between 1598-1821, however, the rate of degradation varied greatly depending on where the impact was occurring, mostly due to the Spanish tradition of concentrating a population in one area, usually along a waterway, and then living only sparsely in the area surrounding the population center (MacCameron 1994). This pattern of intense human impact was evident in the early history of the Mora Valley.

There were several reasons for this pattern of settlement. The first was political as families were granted the rights to tracts of land for their families and their associates. The second was cultural. These associated groups were committed to building a community on these lands, as was part of their tradition. The lands were divided among the land grantees and their associates in a manner that allotted everyone their own small piece of land, while other areas were dedicated as common property, where natural resources were made available to the people as they needed them. The third reason for this settlement pattern was environmental need. Water was a necessary part of settlement and so most groups lived on or near waterways, which in northern New Mexico were often surrounded by semi-arid landscapes. Traditional farming methods adapted by Native Americans to solve this challenge of water needs were also brought from Spain and Mexico with the settlers, and so most settlements created a system of irrigation ditches across the landscape near the settlement in order to have water for domestic use and also to irrigate personal gardens and pastures. These irrigation ditches, known as acequias, were managed in an age-old tradition of community participation and group decision making.

But while many parts of northern New Mexico were populated by Pueblo and Spanish people as early as the 1600's, and by Native American tribes prior to that, the Mora Valley was not settled by anyone until the early nineteenth century. Prior to settlement, the Mora Valley was known and used by many different groups of people, but not cooperatively. Native Americans from all over—Jicarilla Apache, Navajo, Comanche, Pawnee, and the Tiwa people from Picuris Pueblo— visited the Mora Valley in search of wild game. Hispano buffalo hunters (ciboleros) and traders (comancheros) from the western side of the Sangre de Cristos went through the valley enroute to the plains. The first attempt at settlement in 1816, near San Antonio (now Cleveland), by a group of Hispano families, was completely abandoned by 1832 as a result of continuous attacks from the nomadic tribes who visited the Mora Valley. Interestingly, there were signs of the valley's inability to support a high-density population even at this time. Although there were only about 300 people in this first group of settlers, they weren't able to move out across the valley due to the threat of attacks, and so remained clustered together in the settlement. As a result, there was a shortage of water for their agricultural needs. The first of the three trans-mountain acequias, most recently referred to as La Acequia del Rito Negro by Lamadrid and Arellano (2008), was constructed at this time, apparently with the blessing of the people of Picuris Pueblo (Rivera 1998, Arellano 1985). It was the settlers' attempt to supplement their water supply in the Mora Valley settlement. Interestingly, there is considerable disagreement on where exactly this original trans-mountain acequia was located, and it is not in use today (Kryder 2009).

A second attempt at settlement in 1835, with the issuing of the Mora Land Grant to seventy-six families from the west side of the mountains, was more successful (Arellano 1985, Kammer 1992). People resettled in Cleveland, and also in Santa Gertrudis (now Mora), Agua Negra (now Holman) and El Rito de Agua Negra (now Chacon). However, within two years the settlers experienced a water shortage for their crops, and began constructing other trans-mountain acequias. La Acequia del Rito y La Sierra was irrigating crops in the Chacon area by 1865 and La Acequia de la Sierra was constructed in the Holman area beginning in 1879 (Rivera 1998, Arellano 1985). This third attempt was met with a legal challenge from Picuris Pueblo who did not want their water diverted over the mountains. The Pueblo filed a complaint in Taos District Court that was dismissed without prejudice in 1885. These two trans-mountain acequias are still in use today.

The settlers also began moving further down and out of the valley in an effort to find relief from too little irrigable land and the water needed to irrigate it. The population in Mora County had reached 12,000 people by the time the third trans-mountain acequia was constructed, three thousand in the Mora Valley alone (Arellano 1985). This rapid increase in population was due in part by the continual granting of small plots of land in the area to new settlers through the first decades after settlement (Kammer 1992). The establishment of Fort Union in 1851 had caused an additional increase in population and a fundamental shift in land use. Early landowners had been subsistence farmers, growing only enough food for their families and to exchange with their neighbors. Early crops included beans, corn, and other vegetables, such as peas and potatoes that grew well in the rich soil despite the short growing season. Orchards bearing peaches, apricots, apples, pears and plums produced respectable yields in years when spring was gentle to the newly budded trees. Livestock ownership, in keeping with the small size of most farms, was usually restricted to sheep, goats and pigs. With the increasing population at Fort Union and subsequent need for food to feed them, there was a shift from subsistence farming as people began growing cash crops for the government troops (Kammer 1992, deBuys 1985). While people still grew the traditional crops, they increased their yields in order to sell to the fort. In addition, they began cultivating grasses and grains, in particular spring wheat, and later, winter wheat, because these were crops that were always in demand, and were less risky that vegetable crops, which could be wiped out by a single hard frost at the wrong time of the year and had the added benefit of allowing for livestock grazing, as meat was in high demand. Local mills could also grind the wheat, and the added-value crop supported millers and their families as well. For a short time (~ 1860 to 1900), Mora became a leader in agricultural production for New Mexico. By 1890, almost 50 % of the county's lands were being irrigated, including all of the Mora Valley. This was the highest rate of production in the state, at almost four times the average (Kammer 1992). This was lucrative for local farmers but degradation of the land was inevitable.

By the 1920s, the environmental effects from overuse of the land were clearly evident in photos of the valley (Figure 1, also see Table 1 for a timeline of agricultural events). Stripped of nutrients from the constant harvesting, soils eroded and were unable to support the intensive farming effort. Deep arroyos cut like open wounds from the hills above the valley, in some places all the way to the river. The forests ringing the valley were depleted, and the additional erosion of acidic soils downslope contributed to the overall environmental degradation. With the decline of activity at Fort Union subsequent to its closing in 1891, local people, by then used to a cash economy, found it challenging to return to subsistence farming. There was a shift to earning a living off the farm. Cattle grazing and growing alfalfa, which had surged in growth in the surrounding areas like Ledoux and Rociada while Fort Union was active, became more commonplace in the smaller farms in the valley, replacing cash crops. The end result was increased use of mountain lands for grazing during the summer months. This did little to allow the land to heal, nor did it, in the end, benefit the people.

Figure 1. Degradation of the Mora Valley due to overuse of the land. This undated photo from the state archives shows how vegetation has basically been removed from the valley floor, while forests are sparse in the mountains surrounding the valley.

Table 1. Timeline of agriculture in the Mora Valley.

Year	**Event**
1816	Mora Valley first settled by Hispanos from the western side of the Sangre de Cristos
1832	Second settlement of the Mora Valley with the issuing of the Mora Land Grant
1837	First written documentation of water scarcity
1851	Fort Union established
1891	Fort Union closes, collapse of cash crops
1920	Environmental degradation documented in photographs
1950	Most farmland converted to alfalfa and pasture

Early in the twentieth century, a number of events allowed for amelioration of much of the environmental damage. A catastrophic flood occurred in 1904, wiping out most of the valley's established farming lands. This was followed by two abnormally wet decades, and then two abnormally dry decades. Federally funded large-scale farming projects initiated to the south of Mora County were more successful in meeting food demands. Increasing land ownership from outsiders meant lands were divided and fenced. The practice of using common lands for grazing and resource extraction, mainly tree harvesting, was curtailed first by land speculators, who with the collaboration of the territorial government, bought up large tracts of land within the Mora Land Grant and later by the creation of the United States Forest Service (Kammer 1992, deBuys 1985).

While these changes were beneficial for the land, they did not benefit the people, who found themselves struggling to make ends meet in the new economy. Even those families who returned to or never gave up subsistence farming could no longer support themselves solely by farming. People moved away in droves, and the population of Mora County plummeted from a high of almost 14,000 to the current approximately 5,000 people. Those who remain still tend gardens and orchards, raise livestock and grow hay, in much the same way as those who did before them. In recent years, there has been increased interest in returning to small-scale farming (see Table 2), but this time in a community-supported fashion and with the addition of value- added elements to support the shift. Examples of these new farming ventures include the Victory Alpaca Ranch, the Salmon Raspberry Ranch and Tapetes de Lana Weaving Center and Mora Valley Spinning Mill. Also notable are the smaller, family owned small farm businesses, where one or two crops and/or products made from them are sold by the families through the valley's social network or at roadside stands.

In 2014, the state of New Mexico awarded Mora with an Arts and Culture Compound designation which unfortunately continues to perpetuate the myth that "sustainable agriculture is how we've done it for hundreds of years" (www.ourmora.org). However, an article in the January 2014 issue of the Green Fire Times in Santa Fe, New Mexico acknowledges that farming in northern New Mexico has not always been sustainable (Lopez 2014). This is a change from most information written on this subject, which insisted that in the past people treated the land with consideration.

The one constant throughout this turbulent history has been the community's acequia system. The origin of acequias in northern New Mexico is generally attributed to Iberian influence adapted to irrigation ditches constructed by Native people before the arrival of the Spanish (Arellano 2014, Roybal 2012, MacCameron 1994, Rivera and Glick undated). Before the arrival of the Spanish in New Mexico, traditional protocols for the management and sharing of the acequia water had been in place for centuries (Arellano 2014). By the time people settled into the Mora Valley, acequia culture, as documented by many others including Cox (2011), Rodriguez (2006), Rivera (1998) and Arellano (2014), was an established tradition in northern New Mexico. The settlers brought these traditional ways of irrigating to the Mora Valley, and rather than build the system, they had only to build the ditches. Briefly, each acequia is managed by a mayordomo and overseen by a group of commissioners. Parcientes are people who get water from the ditch. There are rules that govern how all management of acequias is conducted. While these may vary from community to community and even acequia to acequia, most are respected and followed by the parcientes. Most newcomers to acequia culture readily embrace it, although more recently the greater number of wealthy property owners from outside the area have been in conflict with these traditions. And often people who have acequia water rights don’t exercise them, because they are no longer interested in farming and do not maintain their fields. In New Mexico, acequias are recognized as self-governing entities, so this tradition continues to this day.

Table 2. Farming trends in Mora County. Although less than 1/3 the number of farms remain since 1910, what has been consistent with farming in Mora County is that roughly half of all farmers since 1950 have held primary occupations away from the farm. Also of note is the reverse of the slow decline in the number of farms from 1978 to the present. From a low of 310 farms in 1978, farming has recovered somewhat with a total of 589 farms identified in the 2007 census, about the same number as in 1959. The number of people per farm reflects a reduction in the number of farms. This is especially acute when you realize that families were much larger before 1940. Number of farms and percent of farmers for whom farming was not their primary occupation came from the USDA Agricultural Census and population data come from the US Census Bureau.

Year	Number of Farms in Mora County	% farming not primary occupation	Population of Mora County	# of people per farm (Farms per 100 people)
1900			10,304	
1910	1,988		12,611	6.3 (16)
1920	1,911		13,915	7.3 (14)
1925	1,576			
1930	1,318	41.8	10,322	8.4 (13)
1935	1,489			
1940	1,232	41.6	10,981	8.9 (11)
1945	1,192			
1950	981	47.8	8,720	8.9 (11)
1954	822	54.6		
1959	576	49.5		10.5 * (10)
1960			6028	
1964	466	45.5		
1970			4,673	
1978	310	54.5		13.6 ** (7)
1980			4,205	
1982	381	55.4		
1987	401	51.9		10.6 *** (9)
1990			4,264	

1997	444	55.0		
2000			5,180	
2002	410	39.5		12.6 ^ (8)
2007	589	61.5		8.3 ^^ (12)
2010			4,881	

Population data from: *1960, **1980, ***1990, ^2000, ^^2010.

Very few acequias in the Mora Valley have been modified in such a way that they are no longer a natural part of the landscape. More often, they remain much the same as when they were first built, although new sections may have been created that changed the flow of water since that time. But physically, a well-maintained acequia will have the same form as when it was constructed, even when naturally dirt lined. Headgates other than of natural rock and short sections of cement lining are the most often seen improvements in the Mora Valley. The youngest of the valley's acequias is over one hundred years old, and most of the acequias are still operational and in use. It appears that they survived the shifts in agriculture relatively intact. This study uses GIS technology to look at changes in both the acequias and agricultural land use in the Mora Valley since the 1950's. We addressed two questions, both looking at how land and water use has changed over the past decades. Once we had answered these questions (see below), this information could be used to address current questions of what effect, if any, these shifts in land use have had on the ecology and hydrology of the acequias. If we are to be successful at the development of new agricultural practices, we need to look at the role of the acequias in these new enterprises. How important are they and will they be in addressing the environmental issues surrounding a resurgence of small-scale farming? We began in the summer of 2009 by investigating two major questions.

The first question asked what changes to current and past land use could we map from historical aerial photos using GIS techniques. From these, we addressed three major hypotheses. They are:

H_1: Acres of farmland irrigated by acequias have declined in recent decades.

Since there has been a decline in personal vegetable gardens and cash crops, we propose that the amount of farmland, defined as fields were a crop or pasture is grown, will be reduced.

H_2: There has been a shift from irrigated farmland to grazing/hay production.

In the time period where aerial photographs are available (1940's to present), it appears that most farmland had already undergone a change to grazing/hay production, but unfortunately there were no earlier aerial photographs available. The assumption was made that indeed there had been a change, but that we may not be able to record it due to the limitations of the photographs available to us.

H_3: There has been an increase in acres of forested land on the slopes above the Mora Valley in recent decades.

Casual study of ground photography over the years has shown that during the mid-21st century most of the hills ringing the valley were devoid of trees, and those hills are now reforested.

The second question looked at how the acequias, stream channels and riparian zones changed in the past few decades?

H_1: There have been no major morphological changes in the acequias, stream channels and riparian zone in the past few decades.

One of the tenants of acequia culture is a management style that seeks to keep acequias and their surroundings as stable as possible. Most improvements to an acequia are meant to keep the system in the same working order as when the acequia was first constructed. This means repairing any damage caused by water damage and erosion and working to conserve the streams that feed the acequias. This management style suggests that we should not see major morphological changes except in cases where major damage from natural forces could not be repaired.

H_2: Areal extent of riparian vegetation has increased along the acequias.

We believe there has been an overall increase in vegetative growth throughout the valley since the shift away from cash crops. This should extend to the riparian areas adjacent to the acequias.

H_3: Aerial extent of riparian vegetation has decreased along the river.

Due to the dry portion of the Mora River being part of the area studied in this project, we believe that there will be less vegetation along the river due to the extent of the drying. Along the river where the waters are not intermittent, we expect to find increased vegetation.

Basically, we did not expect to see any major changes in either land use nor acequia and stream channels since the 1950's, and that minor changes would be in a difference in vegetative growth along stream and acequia channels. The valley and its people appear to have settled into the current pattern after the Second World War, and it is that pattern that exists today. It remains to be seen if this new generation of farmers will change the landscape in the future.

Figure 2. A 1943 photo of the Cleveland Roller Mill in the Mora Valley shows evidence of deforestation caused by over consumption of timber between 1850-1920. Photo is from the New Mexico State Archives online photo catalog.

Figure 3. A 2009 photo shows the same hillside behind the Cleveland Roller Mill. The recovery of the forested slopes is evident. Photo taken by the authors.

MATERIALS AND METHODS

We mapped agricultural and forested land use changes that occurred between 1948 and 2006 and also determined whether acequias could effectively be mapped using aerial orthophotographs. This work was completed in Mora, New Mexico, as part of New Mexico Tech's summer Research Experience for Undergraduates (REU) program "Interdisciplinary Science for the Environment".

In July 2009, the Mora River and four major acequias in the Mora Valley—one on the south side of the Mora River and three on the north side of the Mora River— were mapped using both a Garmin eTrex Legend and a Garmin Geko 201 global positioning systems. Continuous coordinates were taken along the length of the acequias and all water inputs/outputs were recorded and photographed. These data were mapped using ArcMap software. To determine if acequias could be mapped using aerial photos instead of ground-truthing (verifying data through groundwork), additional coordinates were taken along other ditches, and all coordinates plotted first on a topographic map, then layered over a 2006 aerial orthophotograph. Once mapping was completed, we used additional aerial orthophotographs from 1948 and 1964 to investigated changes in land use, specifically extent of irrigated farmland and forest cover. See Appendix A for a list of recorded waypoints.

We used these same aerial orthophotographs to calculate changes in extent of farmland and forested slopes in the Mora Valley using ArcMap. All data were then displayed on a simple ArcMap map, demonstrating the qualitative extent of changes from 1948 to 2006. We did not calculate area for forest expansion as it was not completely a spatial expansion, but also an increase in density that we could see from the photos but we unable to quantify. Quantitative changes in farmland were also calculated using ArcMap.

We were unable to determine riparian changes using the photographs as we were only able to map this for 1964 only.

RESULTS

We determined that further ground-truthing was not required, as identifying the ditches from the aerial photos was just as accurate as using the manually entered coordinates recorded on the ground. When we overlaid our GPS waypoints over the topographic map, they were an almost perfect match (see Figure 4).

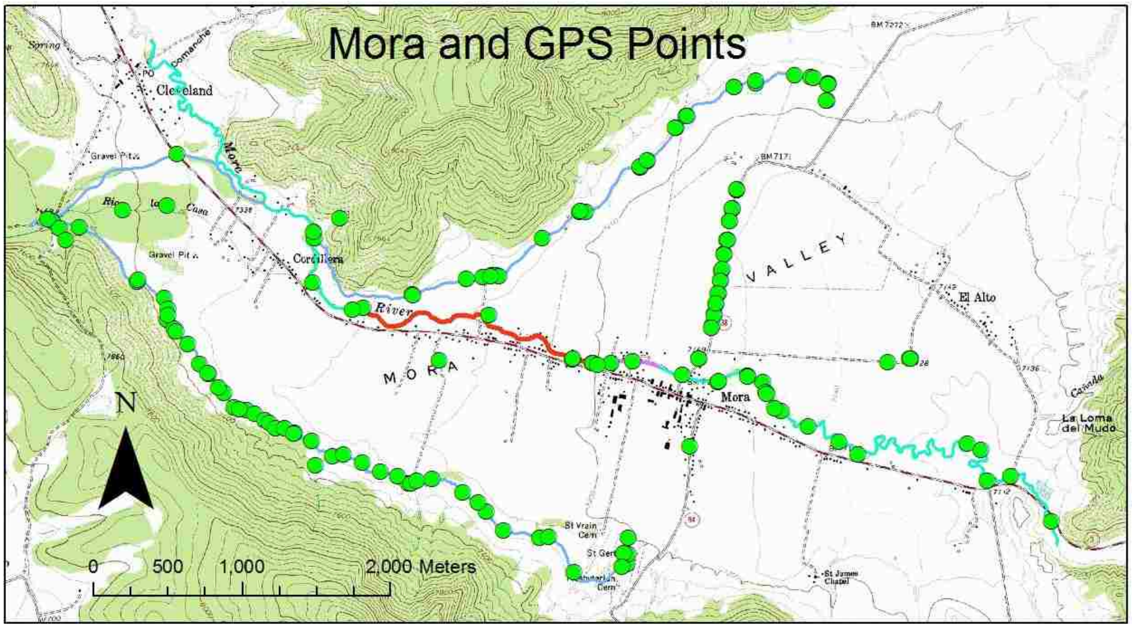

Figure 4. Map of all recorded GPS points used in ground-truthing along the Mora River. The dry stretch of the Mora River is mapped in red.

Once we had determined that we could map the acequias onto the topographic map, we mapped all known acequias on the 2006 aerial orthophotograph (Figure 5).

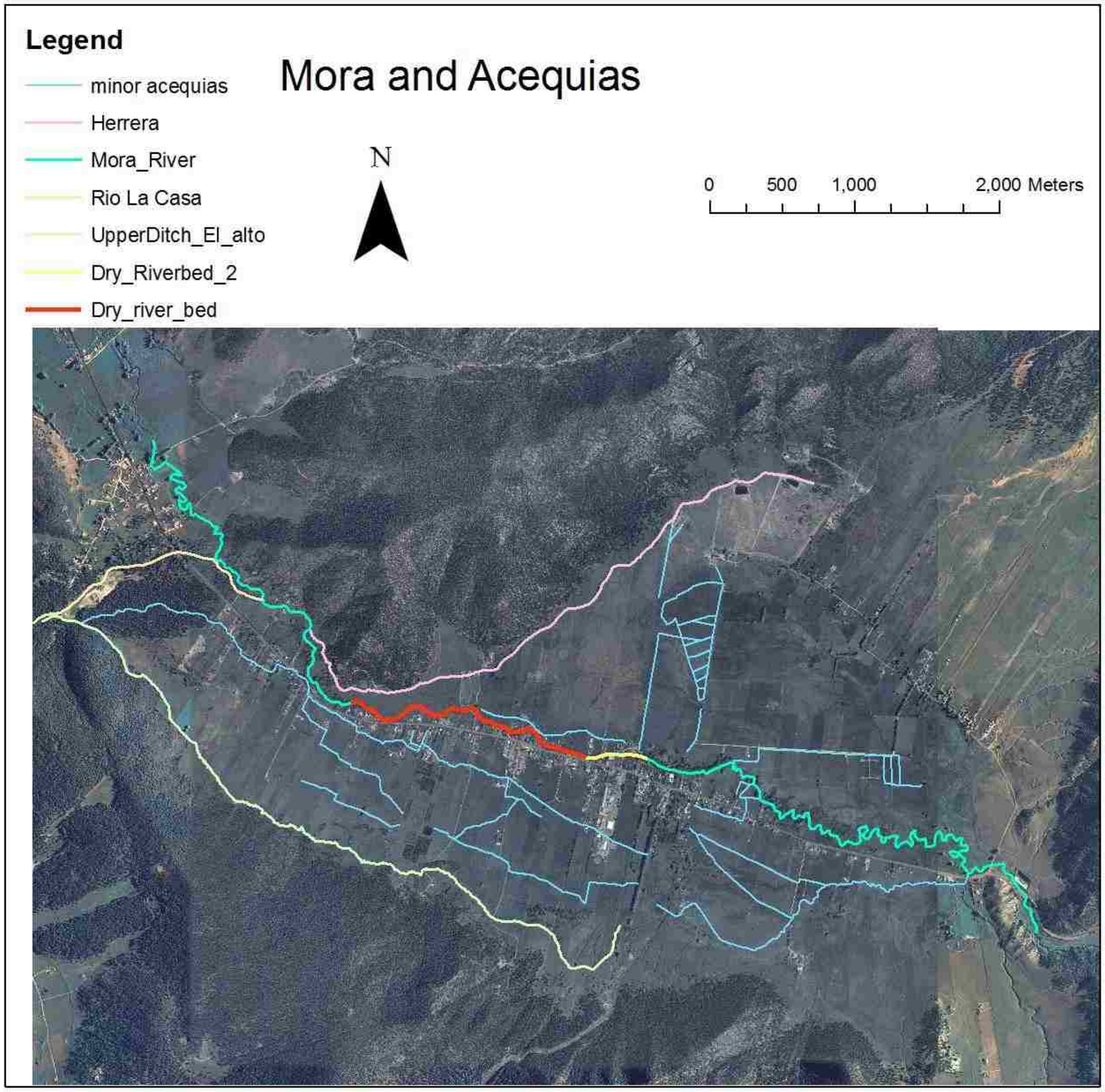

Figure 5. In this map, we have mapped out the acequias in the Mora Valley using ArcMap. None of these lines were created using waypoints but instead were traced by eye.

We then mapped the GPS waypoints directly onto our aerial photograph and again waypoints aligned with our acequia positions. Acequias can be mapped using aerial orthophotographs alone.

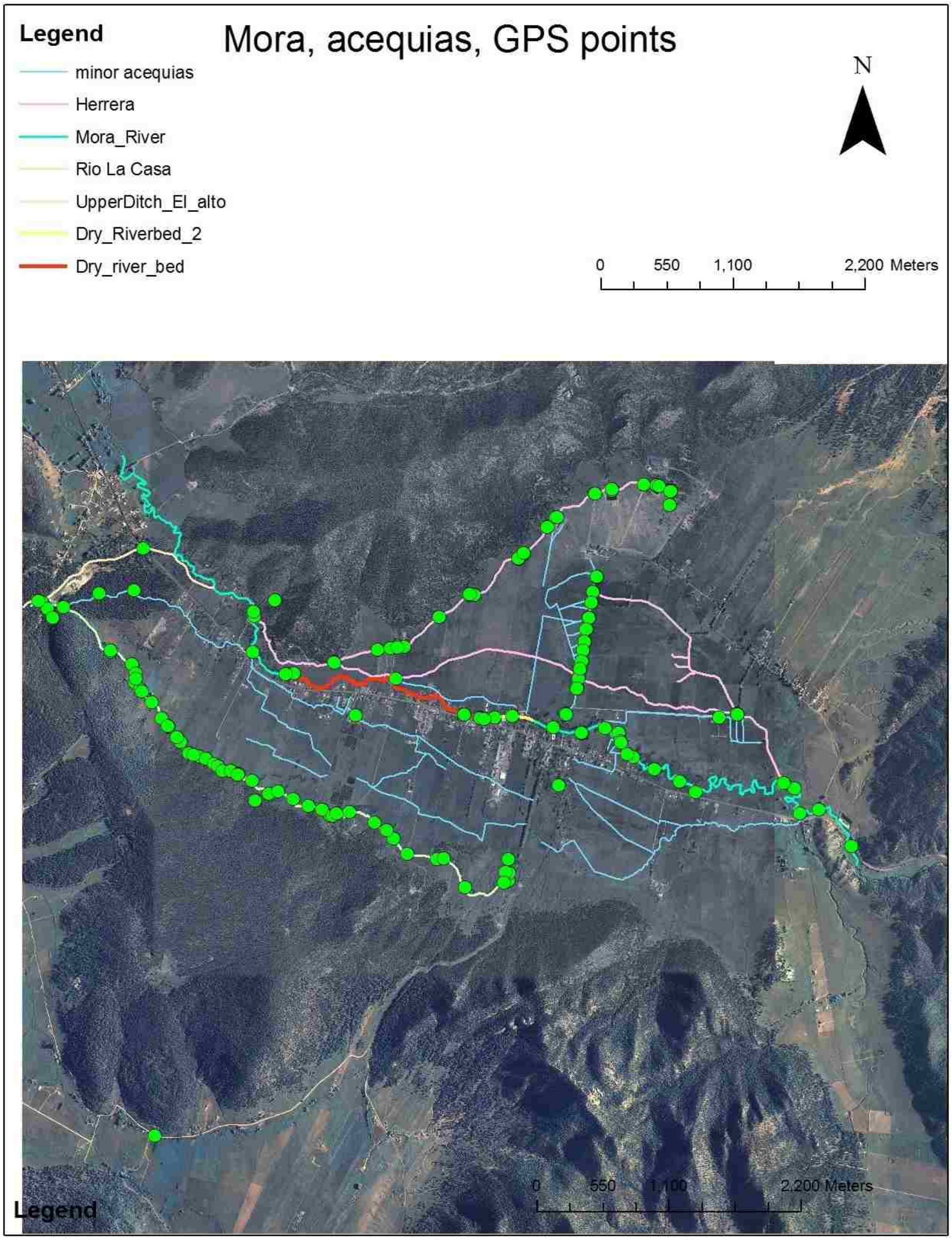

Figure 6. This map shows the waypoints combined with the acequias outlined using ArcMap. The dry segment of the river is mapped in red and yellow.

We were able to determine both areas of irrigated land and the lower treeline in all aerial orthophotographs (see Figures 7, 8 and 9). These were overlaid in a single ArcMap for analysis (see Figure 10).

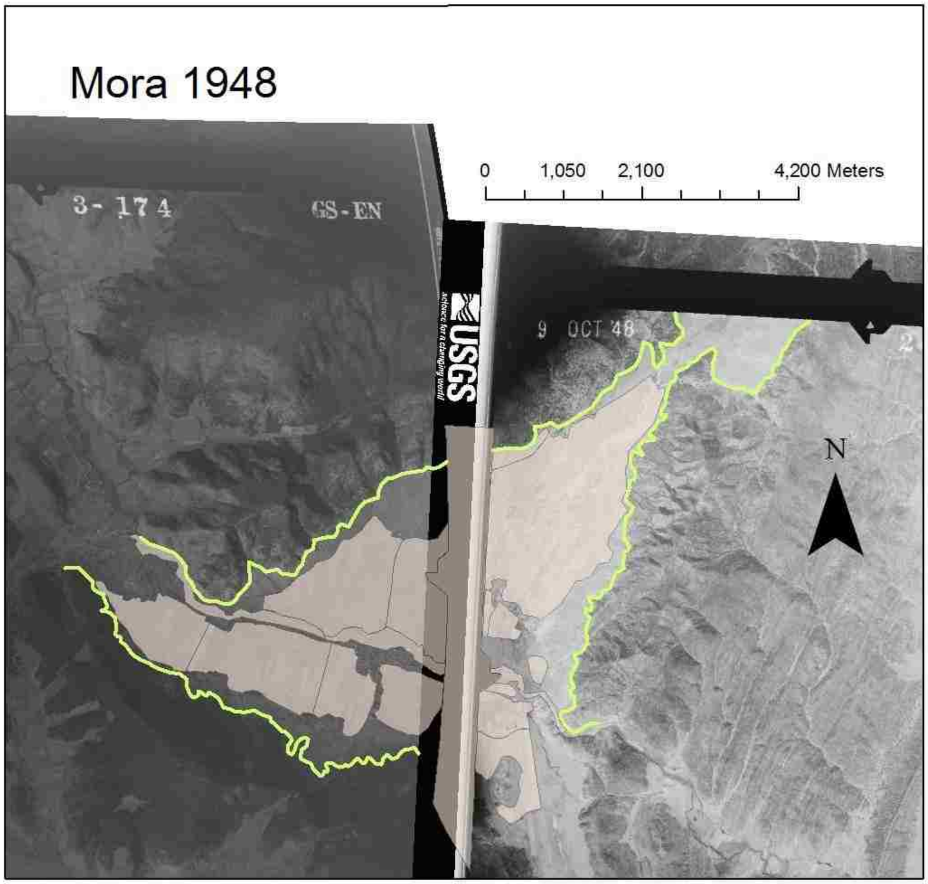

Figure 7. USGS orthophotograph of the Mora Valley in 1948. Agricultural land is outlined in tan and the yellow outline traces the tree line.

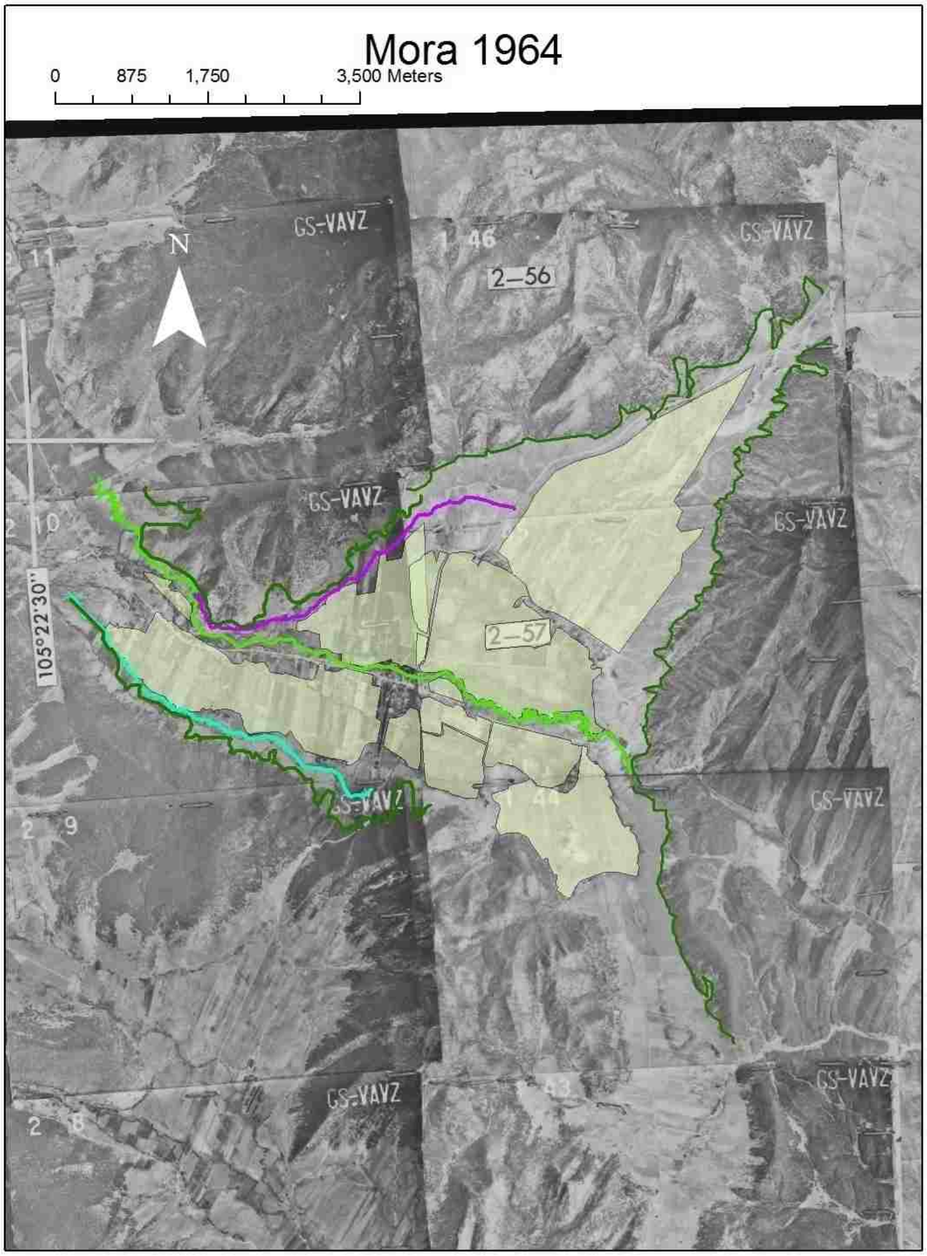

Figure 8. Mora Valley 1964. Agricultural land in highlighted in light green and tree line is outlined in a darker green.

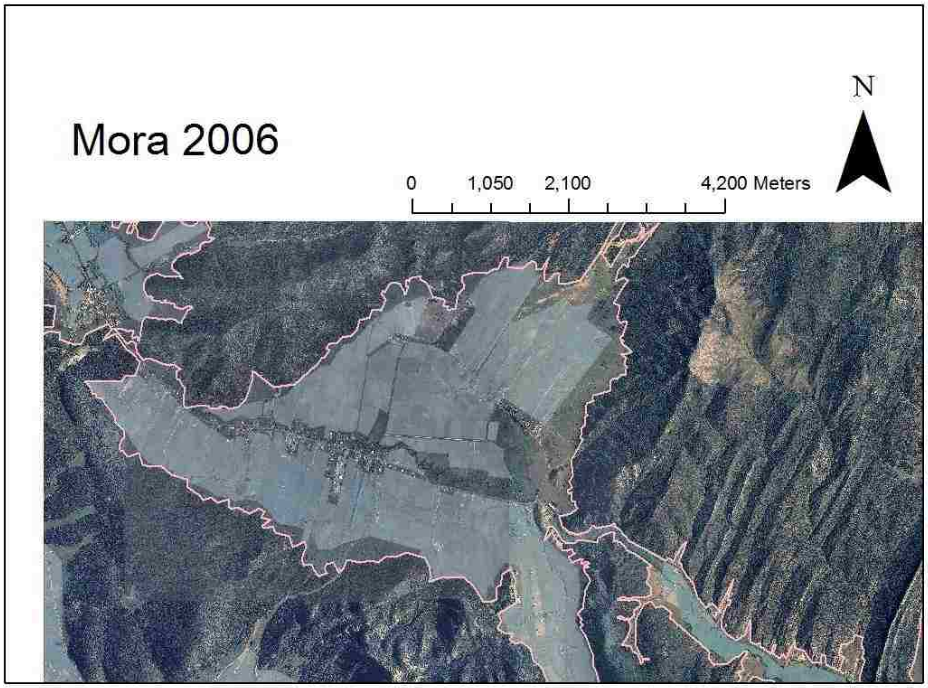

Figure 9. Mora Valley in 2006. Farmland is indicted by light grey, tree line by pink.

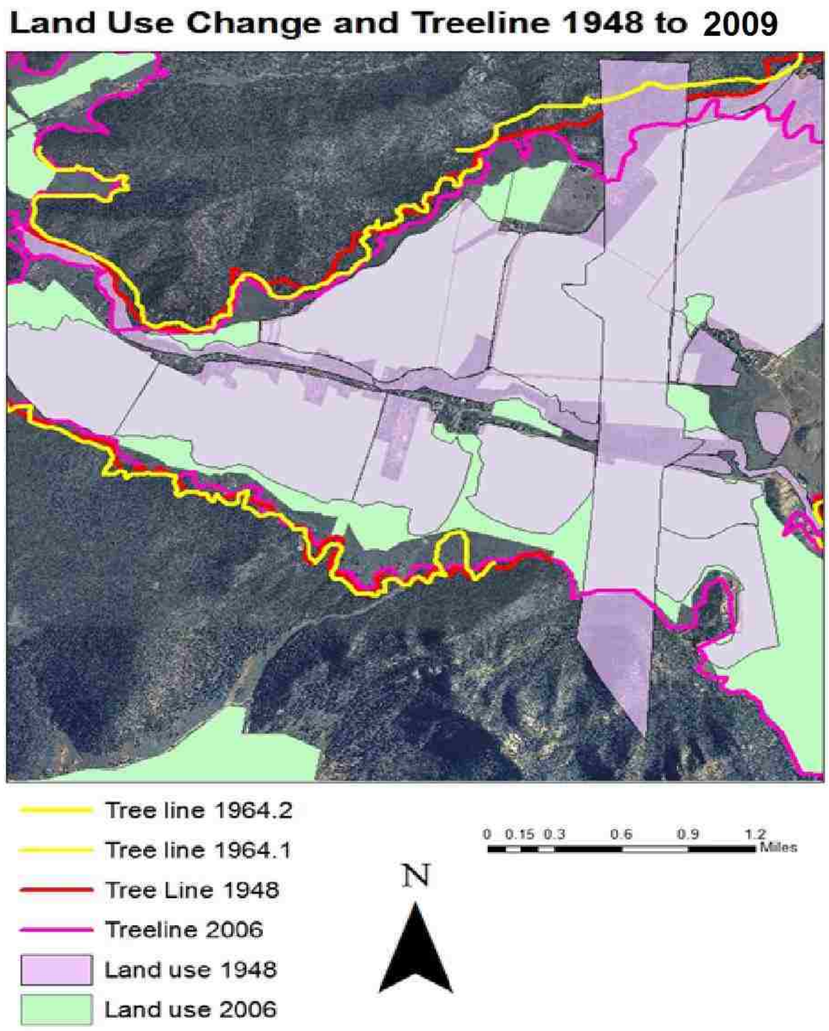

Figure 10. Summary map of land use changes in the Mora Valley.

Between 1948 and 2006, there was approximately a 100-acre reduction in farmland. In 1948 and 1964, 2800 acres were being farmed. By 2006, that had only been reduced to 2700 acres. Patterns of canopy cover suggest that a majority of this farmland was being used to grow hay. In addition, forest cover increased between 1948 and moved downslope over time.

DISCUSSION AND ANALYSIS

There were two major outcomes of this study. The first was that we were able to successfully ground truth work we had done using GIS technology to determine if it were possible to do the analysis using GIS techniques alone. We had an almost perfect match to the points we collected in the field and the points we created using the software alone. At the time of the study (2009) this was important work, as this methodology was starting to be routine, but not much had been done to ground truth mapping done on large areas of study. Our purpose was to show that community groups, who often don't have the equipment, time or expertise to do this kind of mapping on their own, could use maps created by experts who do not have place-based knowledge, but can still provide assistance to local groups. There had been a general disconnect between the scientific community and community groups that has, in the years since, seen movement towards collaboration. While complex use of GIS technology still remains mostly accessible in scientific research, simple GIS mapping has become an everyday part of life for most landowners, local governments and community groups. However, at the time of this study, this was not the case in northern New Mexico, and our question of whether GIS technology would work at the local scale without manual coordinate acquisition was valid.

The second major outcome of this study was the results of our hypotheses, summarized in Table 3. The first major hurdle we faced was a lack of very old aerial photographs. From historical documents and anecdotal evidence, it was apparent that the irrigated portion of the Mora Valley's agricultural lands had gradually changed from cropland to grazing and hay production after the closure of Fort Union and the flood of 1904. An 1874 map drawn by Lt. Wheeler of Fort Union showed all of study area as irrigated and under cultivation of crops (Kammer 1992). However the earliest photograph we had was taken in 1948 and showed most of the area in grassland. So we had to begin our analysis after this major shift from crops to pasture was complete.

Subsequent photographs show that this shift has been stable up to 2006. While we did determine that approximately 100 acres of cropland had been lost in six decades (from 2800 irrigated acres in 1948 to 2700 in 2006), this loss of cropland is relatively minor and can be explained by the reduced or extinct family gardens common in rural communities in the past. With so many people having jobs outside the community, finding time to garden as people did in past generations is a challenge. This, along with the now ready availability of fresh produce for purchase, could easily explain this reduction in cropland. While there has, in recent years, been a movement of young people moving into or staying in the valley to embrace this old way of living, the large family garden has been replaced by kitchen gardens, raised beds, and smaller harvests. Old orchards still remain, but few are tended as in the past and few new orchards are developed. A family may have fruit trees, but more often they are interspersed with landscaping around the family home than in a standard orchard formation.

When you are land rich and money poor, and working a job off the land, it is easy to understand why the valley's landowners chose to abandon their large gardens and smaller livestock, which require much care, for cattle and hay production. A well-grazed cow is much more cost effective, requiring only growing grass and tended fences to produce a year's worth of meat for a family of five. Many families, to this day, do not provide much hay for their own livestock, because they have enough land, leased or owned, to graze them year around. So hay production, for most, provides additional income for landowners. Both hay and cattle, however, need irrigated fields to thrive and so most landowners continue to irrigate these pasturelands, perpetuating the acequia culture developed by earlier generations. Acequias are routinely maintained and water is still used by a majority of landowners. Part of this comes from the "use it or lose it" mentality, some of it comes from pride in cultural traditions, and some of it comes from the need to use the land in a productive manner because it contributes to the overall survival of the people.

The "use it or lose it" mentality comes from the fact that water has always been scarce in northern New Mexico. Although lack of water is not typically a problem in the Mora Valley, due to extreme variability in weather patterns, there are dry years. During those periods, value of available water increases and this long ingrained attitude surfaces. Water sharing in times of scarcity is a traditional value of acequia culture. Management of water on individual acequias is determined by the members of that acequia, with discussions between connected acequias that often led to cooperative agreements. Problems most often arise on smaller acequias, because scarcity is not common, and when it is, there is more of an "us versus them" attitude than cooperation. It is imperative that these smaller acequias discuss these issues before there is a problem. This is what has been successful for the larger acequias. Protocols in place to address a lack of water are often many generations old. Acequia culture is a strong force holding together communities when water is scarce.

People in northern New Mexico are often land rich and money poor. Land is often the most valuable possession a family owns, and for many it is land passed down through generations. This land is very seldom sold, but it is shared, and sometimes divided. Ranching is a way to maintain family land, and give the family enough food or money to offset taxes. Acequias are maintained because fields must be irrigated to give the highest return.

Table 3. Summary of hypotheses addressed by this study.

Hypothesis	**Determination**
Irrigated land has decreased in size	True, by 100 acres
There has been a shift from irrigated cropland to grazing/hay production	True, but this happened prior to this study
Upslope forests have increased in size	True
There have been no major morphological changes to acequias	True
There have been no major morphological changes to stream channels	True
There have been no major morphological changes to riparian zones	True
Riparian vegetation has increased along acequias	Probably false, but further study is needed

The Mora Valley is ringed by a thick green forest of pine species, including ponderosa pine and gambel oak. Yet photographs taken early in the twentieth century show these slopes devoid of trees. Overuse of local wood resources by the much greater population of the time is the accepted explanation. Our analysis of the aerial photographs showed the forest's return. Kammer (1992) noted the lower treeline over time and suggested gambel oak had replaced the pine trees. I don't believe this to be the case, however, it is possible that the oak was much less dense prior to reforestation.
Many very old fence posts still in use in the Mora Valley are made of oak, which suggests that oak has been plentiful in the years since reforestation. Gambel oak generally grow among and slightly lower in elevation than ponderosa pine, so it is possible that the lowering of the treeline we see in the aerial photographs is the result of oak moving downslope. More dramatic than the analysis we conducted is a simple comparison of photographs of the denuded slopes from the early decades of the twentieth century and those of the same area taken today (Figure 2).

A critical component to the questions we asked in other parts of this study is how the connectivity of the surface hydrology in the valley has affected the ecology of the acequias and the Mora River. Since the acequias are over a hundred years old, are they now a part of the ecosystem or are they still a human intrusion that alters the natural processes in the valley? One aspect of that question addressed in this work was to look at changes, if any, we could find in the course of the river or the location of acequias. Unfortunately, we did not complete an analysis of the course of the Mora River. We could find very little change from hiking the length of the river through the valley. There was however, recent stream channel movement in Luna Creek, upstream of the Mora River, and an area used in another part of our overall study. This was the result of the presence of beavers in the area. Since we also found evidence of beaver dams in the river at the lower end of the valley, it is possible that that section of the river has experienced some changes since 1948, however none was evident from an examination of the aerial photographs. We were able to analyze the major acequias used in this project, and they did not show any channel movement over time, so we can assume that most of the acequias in the Mora Valley have been maintained in their current locations since the 1950s. In addition to the maintenance of acequias, there is evidence from the ground to suggest that the course of the river through the middle of the valley has been altered considerably by human interference, as only the upper and lower reaches of the valley's watercourse shows natural meanders. However, as with the acequias, these changes in the channels are very old and relatively stable.

Our final question was whether riparian vegetation had increased over time along acequias and the river due to increased connectivity across the landscape. This question proved too complex to approach without employing additional technology. Our focus for this work was to determine if simple GIS techniques could be used by community groups to compliment scientific study. We believe that the techniques used here, combined with additional field techniques, such as Fleming's acequia assessment tools (Roybal 2012), allow active participation of community groups that can also provide place-based information to scientists and government agencies that can use to assist them in regulation of surface waters.

Climate change has become the focus of much research into future impact on water quality. However, there is evidence to suggest that land use changes may have a greater impact on water quality and other ecosystem services in the foreseeable future (Hanratty and Stefan 1998). We are already altering the way we manage water resources based on anticipation of climate change models. There needs to be acknowledgement of the connectivity between water resources and the lands they pass through so that they are treated as one ecosystem and not parts separate from each other.

Community groups are in the forefront of this connection. They have become the monitors of local water quality, scientists' "boots on the ground" as it were. This is an important link to place-based knowledge, a sharing of what local people and scientists know and understand.

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LITERATURE CITED

Arellano, A.S. 1985. Case Study: Acequias de la Sierra and early agriculture of the Mora Valley. Research Paper. Center for Land Grant Studies. Guadalupita, New Mexico.

Arellano, J.E. 2014. Enduring Acequias: Wisdom of the Land, Knowledge of the Water. Querencias Series. University of New Mexico Press. Albuquerque, New Mexico.

Cox, M. and J.M. Ross. 2011. Robustness and vulnerability of community irrigation systems: The case of the Taos Valley acequias. Journal of Environmental Economics and Management 61: 254-266.

DeBuys, W. 1985. Enchantment and Exploitation: The Life and Hard Times of a New Mexico Mountain Range. University of New Mexico Press, Albuquerque.

Hanratty, M.P. and H.G. Stefan. 1998. Simulating climate change effects in a Minnesota agricultural watershed. Journal of Environmental Quality 27(6): 1524-1532.

Kammer, D. 1992. Report on the Historic Acequia System of the Upper Rio Mora. New Mexico Historic Presentation Division.

Kryder, L.R. 2009. The trans-basin acequias of the Mora Valley, New Mexico: A working paper. Unpublished.

Lamadrid, E.R. and J.E. Arellano. 2008. Juan the Bear and the Water of Life. University of New Mexico Press, Albuquerque, New Mexico.

Lamadrid, E.R. and J. E. Arellano. 2014. Oral Tradition and Legal Authority in the Trans-Mountain Acequia Systems of the Mora Valley, New Mexico. *From* Sanchis-Ibor, C.; Palau-Salvador, G. Mangue Alférez, I.; Martínez-Sanmartín, L.P. (Eds.) Irrigation, Society, Landscape. Tribute to Thomas F. Glick, València, Universitat Politècnica de València. doi: http://dx.doi.org/10.4995/ISL2014.2014.182

Lopez, A. 2014. A bird's-eye view of Northern New Mexico's acequias. Green Fire Times 6(1): 7-10.

MacCameron, R. 1994. Environmental change in colonial New Mexico. Environmental History Review 18(2): 17-39.

Rivera, J.A. 1998. Acequia Culture: Water, Land and Community in the Southwest. University of New Mexico Press, Albuquerque.

Rivera, J.A. and T.F. Glick. Undated. The Iberian origins of New Mexico's community acequias. www.taosacequias.org/Documents/GlickRivera409.pdf

Rodriguez, S. 2006. Acequias: Water Sharing, Sanctity and Place. SAR Press, Santa Fe, New Mexico.

Roybal, M. 2012. Measuring Acequia Functionality: Developing a tool for assessing New Mexico’s community based irrigation systems. Unpublished Professional Project. University of New Mexico, Albuquerque. 123 pp.

United States Department of Agriculture. 2009.Agricultural Census. www.agcensus.gov

CHAPTER THREE

Annual patterns of aquatic macroinvertebrates in acequias resemble those in IRES

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ABSTRACT

Acequias are traditional earthen irrigation ditches connected to natural waterways that are still widely used in the southwestern United States. Social and ecological scientists have suggested that acequias contribute positively to the overall biodiversity of an ecosystem due to their age and because they function as intermittent streams that play important ecological roles. This is the first study to test that assertion of functionality for aquatic macroinvertebrates. Six sites in the Mora Valley, northern New Mexico, were sampled over the course of a year. Three perennial sites were on the Mora River, and three sites were intermittent in acequias that come off that river ecosystem. Physical and chemical parameters were measured, and macroinvertebrates were collected during 2012-2013. Patterns in the richness, abundance, and community structure of macroinvertebrates and the key influences that drive them were examined to determine the differences between habitats (river versus acequia), seasons, and sites. Richness was significantly different between acequias and the river due to flow regime and substrate, which could be explained by examining life history strategies and the effects of disturbance on the river system. Macroinvertebrate abundance and overall community structure were not significantly different among seasons, sites, and habitat. We conclude that acequias are much like intermittent streams and assumptions associated with studies of intermittent streams can be applied to acequias.

Keywords: Intermittent streams, IRES, acequias, aquatic macroinvertebrates, community ecology

INTRODUCTION

Up to one-third of the world's waterways, and more than half of those in the United States, consist of small stream ecosystems that often are not represented on maps and are rarely considered in the aquatic studies of a region (Larned et al. 2010, Arthington et al. 2014, Datry et al. 2014, Leigh et al. 2015). Research focus has been on the hydrology and ecology of perennially flowing streams and rivers (Vannote et al. 1980, Junk et al. 1989, Ward et al. 1989, Montgomery 1999, Thorp et al. 2006) rather than these smaller intermittent streams. Interest in flow regimes and ecology of small low order streams has increased, however, because these streams will likely be the first affected by climate change (Larned et al. 2010, Rupert 2012, Bogan et al. 2013) and are recognized as having an impact on stream health disproportional to their size (Armstrong et al. 2012).

One of the challenges in studying these networks of very small streams is their variable flow regime. The majority of these streams are either intermittent or ephemeral, meaning they have periods during their annual cycle when they do not flow. Although they may seem perennial in nature for a portion of the year, those times when they do not flow have consequences for their biological structure and ecological function. A perennial stream is one that flows constantly throughout the year, even though there are changes in flow velocities and stream discharge. Streams that cease to flow have been characterized by many different definitions (Arthington et al. 2014). For the purpose of this paper we will use the recently proposed acronym IRES (Intermittent Rivers Ephemeral Steams) as the term for all waters that cease to flow at some point along their course during the year (Datry et al. 2016).

Regardless of whether they arise in mountain headlands or valley lowlands or whether they are found in mesic, semi-arid or arid environments, IRES do not flow year round. While the period of annual dryness varies considerably, this lack of flow has consequences for the aquatic inhabitants of these streams. A large number of studies have investigated what characteristics of IRES have the greatest impact on aquatic macroinvertebrates (Stanley et al. 1994, Williams 1996, Bogan et al. 2013, 2014, Schriever et al. 2015). These studies agree that key characteristics, such as discharge, flow velocity, and water quality, differ in IRES compared to perennial streams, and that these and other biological and physiochemical parameters, such as substrate type and life history strategies, affect biodiversity, although not always in a consistent way.

Although IRES have only recently drawn considerable attention from scientists (Leigh et al. 2015), they are of significant value in local communities where they are a resource, and a large body of place-based knowledge exists (Rivera 1998, Rodriguez 2006, Rupert 2012, Armstrong et al. 2012, Arellano 2014, Datry et al. 2016). In northern New Mexico, these small stream systems have been expanded in the past few centuries by the development of irrigation ditches, called acequias, which mimic the natural form and function of small intermittent streams (Rupert 2012). They are human-made intermittent streams because they experience predictable drying periods of several weeks to several months annually due to human control of flow regimes. In addition, they are designed to follow the contours of the land, and often meander rather than cut directly and linearly through the landscape. Even the newest of the acequias in northern New Mexico are at least one hundred years old; acequias act as part of stream network connectivity in the areas where they flow (Fernald et al. 2006, Fernald and Guldan 2007).

Two things make acequias different from most irrigation ditches: 1) they have a centuries-old cultural heritage of communal management practices that are still in use today and include annual cleaning, removal of organic debris, and periods when all water is removed from the ditches, and 2) they are associated with small, family-owned, generally organic, farms and grazing land. These deviations from modern irrigation technology, combined with the age of many of these human-constructed ecosystems, may allow us to classify them as IRES.

Patterns in the richness and abundance of benthic macroinvertebrates were examined to answer two main questions. First, what are the differences in aquatic macroinvertebrate patterns between river and acequia sites? Second, what are key influences on these patterns within river sites and acequia sites? We investigated three major hypotheses: 1) Differences in water quality and physical parameters linked to flow in the acequia system will affect aquatic macroinvertebrate patterns. 2) The abundance and taxa richness of aquatic macroinvertebrates will be higher at river sites than acequia sites because flow is not interrupted at the river sites. 3) Differences in aquatic macroinvertebrate community structure between the acequia and river sites will exist because of differences in flow regime, water quality, and other physical parameters. This is the first year-long study investigating the aquatic macroinvertebrate ecology of acequias and their source waters, and will contribute to understanding similarities and differences between rivers and acequias that share the same water source.

MATERIALS AND METHODS

Site description

The Mora River is a tributary of the Canadian River in northern New Mexico. The headwaters of the Mora River are 3660 meters above sea level in the Sangre de Cristo Mountains (the southernmost segment of the Rocky Mountains); and the river is over 160 km in length from headwaters to its discharge into the Canadian River at 1420 meters above sea level. The Mora River flows from west to east with headwaters emerging from high gradient montane catchments. While the overall gradient in Mora County is 16 m km^{-1}, the study area has a slope of 19 m km^{-1}. The mountain terrain gives way to open plains a few kilometers below the study sites, about halfway through the river's length. The drainage area is ~44,800 hectares. Along most of its length, the waters of the Mora River are diverted into forty-seven major acequias (Kammer 1992). Most acequias are used for irrigation of pastureland and hayfields, although some support what remains of subsistence farming in the valley. Each acequia is managed separately from the others. Decisions on one acequia are made without regard to the natural flow of the river or the effect management decisions will have on other acequias. As a result, a 3.4 km stretch of the Mora River is often completely dry, except during early spring runoff. At other times, flow in this area is greatly reduced or may even cease. The affected section begins just upstream of the village of Mora. Two major acequias, in close proximity to each other, divert water away from the Mora River at this point and across the floodplain in the central valley. Most of the water, however, is not used, and these return flows are redirected back into the river just downstream of the village. At the point downstream of where these acequia flows return to the river, the river is once again perennial.

This study includes section of the watershed contained within Luna Canyon (headwaters) and the Mora Valley. Luna Creek is one of two first-order streams that merge to form the second-order Mora River above the village of Chacon. The river then runs through the valley, and most acequias branch away from the main channel and then return to the river in this reach. There are six locations that were sampled in this study: one perennial flow site on Luna Creek at the headwaters, two perennial flow sites on the Mora River (one above the dry stretch and one below) and three intermittent flow sites on separate acequias that come off the river between these two lowest river sites. Sites were selected based on location and accessibility (Table 1, Figure 1). The six study locations (each containing three replicate sampling sites along a single reach) were determined using US Geological Survey topographic maps and ground reconnaissance. Once a suitable location was identified, GPS coordinates were recorded in UTM NAD 27 (CONUS) and sites were photographed (Figure 2). Field surveys were completed a total of eight times (twice in each season) between May 2012-April 2013. Actual survey dates were May 3-4 (mid-spring) and July 7-12, 2012 (early summer), August 29-September 10 (mid-summer) and October 5-8, 2012 (early fall), November 5-7, 2012 (mid-fall)) and January 3, 2013 (early winter), and February 16-20 (mid-winter) and March 30-April 1, 2013 (early spring).

Water quality

Water quality measurements were made at the replicate sampling site furthest downstream at each study location prior to macroinvertebrate collection. Water temperature (°C) was recorded using a Barnard digital thermometer with a K-type thermistor. Dissolved oxygen concentration (mg L^{-1} and % saturation) were measured using a Sper Scientific dissolved oxygen meter (#850041). Measurements of pH, conductivity (μS cm^{-1}), total dissolved solids (TDS) (mg L^{-1}), and salinity (ppm) were taken using an EXTECH EC500 handheld multimeter. A second handheld pH meter (Hanna Instruments HI 98127) was also used beginning with the early fall sampling. Water clarity was recorded as 1) clear (can see bottom of streambed), 2) slightly turbid (bottom is hazy) or 3) muddy (cannot see bottom).

Physical variability

Substrate type was determined using a modified Wentworth Classification for particle size (Allen 1995). The two dominant substrate types observed at each replicate sampling site were assessed in early fall. Average flow velocity was determined using a flotation method for velocity (υ) repeated five times at each study location during each sampling event (Resh et al. 1996). The average flow velocity (in m s^{-1}) calculated and along with wetted channel width and average depth, calculated from ten sample depths recorded across the wetted channel at each sampling site, were used to calculate discharge using the equation from Resh et al. (1996):

$$Q\ (m^3\ s^{-1}) = W\ (m) \times D\ (m) \times \upsilon\ (m\ s^{-1})$$

The mean of the three replicate sampling sites was used as a single measure of discharge at each study location.

Aquatic macroinvertebrate sampling and analysis

Sampling for benthic aquatic macroinvertebrates was conducted twice each season at all locations. Three replicate sampling sites were selected at each end and in the middle of an approximately 100-meter reach. From each replicate sampling site on the perennial streams (R1, R2, and R3), three sub-samples of aquatic macroinvertebrates were collected from 1 m^{-2} area in three locations across the stream channel using a Wildco (Yulee, Florida) kick net. If the stream was not wide enough to accommodate three separate sub-samples, one or two sub-samples were collected. In acequias (A1, A2, and A3), a single sample was collected most of the time using this same methodology. Sub-samples were transferred to labeled sampling containers and preserved with 95% ethanol. For both river and acequia sites, aquatic macroinvertebrates were identified to family using a Leica Zoom 2000 dissecting microscope and taxonomic invertebrate keys (Merritt et al. 2008, Rufer and Ferrington 2006, Ward et al. 2002, Voshell 2002). Voucher specimens were maintained and catalogued. Sample count was conducted using a Luxo Magnifier Lamp with a 2.25X magnification. Family richness and abundance m^{-2} were calculated for each sub-sample. Collections were subsampled in cases when densities were extremely high. We used the Ephemeroptera, Plecoptera and Trichoptera (EPT) metric as an indicator of biological integrity in our study. Developed by Lenat (1988), the EPT index uses richness as an indicator of water quality. The higher the number of EPT taxa at a site compared to other taxa, the better the water quality of the stream. We used overall richness (# of taxa) for the EPT index and also calculated EPT % abundance (Total EPT taxa /Total taxa) x 100.

Statistical Analysis

One-way analysis of variance (ANOVA) and Pearson Chi Square were used to compare physical and chemical variables, total taxa richness, which was calculated from Menhinick's Richness Index (1964), EPT richness and taxa abundance (individuals m^{-2}) among sites, season, and habitat. None of the data were transformed. Some of the invertebrate data was analyzed at the level of order, although most taxonomic analyses were completed at the family level. JMP 12.1.0 (SAS Institute, Inc. 2015) was used for all univariate analysis. Families with rare taxa (less than 10 individuals) were removed from the analysis. Significance was $\alpha = 0.05$.

Multivariate analyses were completed with PC-ORD 6.0 (MJM Software 2010) using Sorenson's (Bray-Curtis) distance measure for all analyses. We used nonmetric multidimensional scaling (NMDS) to visualize the overall patterns in macroinvertebrate communities. Because our original dataset contained counts for each replicated sample site, data were averaged among sites for this analysis. The data were analyzed with the default setting of PC-ORD with 250 iterations via Monte-Carlo runs with 50 real and 50 randomized runs. To interpret the results, we examined correlations with the non-categorical abiotic factors to determine their influence on the community by adding vectors to the resulting diagrams to determine relative influence of the abiotic data and site/sample characterization on macroinvertebrate patterns. Kendall's tau were used to lexamine the contribution of each taxa to patterns observed between habitats (river versus acequia). We used a multi-response permutation procedure (MRPP) to identify relationships among the invertebrate communities based on *a priori* groupings (river x acequia, all sites, and all seasons), providing T scores, a statistic A (representing strength of each variable on community abundance patterns) and a p-value for the significance of that relationship. The Mantel test was used to confirm the correlations found with MRPP between the macroinvertebrate abundance data and abiotic factors.

Finally, Indictor Species Analysis was used to link taxa with habitat (river or acequia). This method constructs Indicator Values for statistical significance using the Monte Carlo test to look for representative taxa by combining relative taxon abundance with that taxon's relative frequency in each habitat. A threshold level of indicator values greater than 50% that also had a 95% significance ($p\text{-value} < 0.05$) was chosen as the cutoff for identifying indicator specie (Dufrene and Legendre 1997). We did this analysis for habitat only based on De Caceres et al.'s (2010) paper demonstrating that indicator species analysis was more rigorous when combining groups of sites into more broad-based environmental grouping if taxa were present at most sites.

RESULTS

Water quality

There were few significant differences in water quality measurements among seasons, sites and habitat type (Table 2). Season significantly affected temperature (F=16.5078, p= <0.0001, annual mean = 11.2 °C, S.D. =±4.40), but temperatures were not significantly different among sites or habitat type throughout the year. Dissolved oxygen was also significantly different by season (F=5.4505, p=0.0449, annual mean = 96.46 %, S.D. ±13.43) but not different between habitat and site. Values for pH were also not influenced by site or habitat, but were affected by season (F=5.4504, p=0.0046, annual mean = 8.65. S.D±0.39). Differences in conductivity, salinity, and TDS were not significant between river and acequia habitat types, but there were differences among sites: conductivity (F=44.4129, $p < 0.001$, annual mean =425.40 μScm-1, S.D. = ±143.52), salinity (F=25.0960, p <0.001, annual mean = 221 ppm S.D. = ±66.15) and TDS (F=44.2568, p <0.001, annual mean = 304.22 mgL-1, S.D. ±93.78). In each case, R1 and A1 were different than the other four sites in that conductivity, salinity, and TDS were all significantly lower. TDS was significantly affected by season (F=3.2919, p=0.0326), being lowest in the spring and then progressively becoming higher throughout the year. Conductivity was also significantly affected by season (F=3.5029, p=0.0257) and also increased in concentration throughout the year, being lowest in spring and highest in winter. Salinity was not significantly affected by season, despite the strong interrelationship among these three water quality measurements.

Physical parameters

There were greater differences between sites and habitat when we look at physical characteristics versus water quality measures. Wetted channel (F= 49.9907, p <0.0001, annual mean at all sites = 265.62 cm, S.D. = ±110.86), flow velocity (F= 10.8533, p = 0.0035, annual mean = 2.34.m s^{-1}, S.D. = ±3.20), and discharge (F=6.8076, p=0.0168, annual mean = 0.59, S.D. = ±0.60 m3s-1) were significantly different when comparing river and acequia habitats. Discharge (F= 2.9264, p=0.0461), flow velocity (F=10.5361, p=<0.0001), wetted channel (F= 11.3346, p = <0.0001) and average depth (F=5.5677, p=0.0023, annual mean = 9.97 cm, S.D. = ±9.75) were all significantly different by site (Table 2). There were no significant differences between hydrological parameters by season. Substrate was significantly different by site (r^2= 0.8694, p= <0.0001) and habitat type (r^2= 0.2756, p = 0.0005), but not by season. All sites contained cobble as one of the dominant substrates but other substrate, with the exception of sand and silt, varied among all sites. All acequia sites contained sand but not silt, and the opposite (silt but not sand) was found at all river sites.

Aquatic macroinvertebrate richness

Seasonal patterns of richness were not statistically significant (F = 0.8186. p = 0.5792) but variation was still evident. Beginning in mid-spring, there is a slight rise in richness, until mid-summer, when richness falls off gradually until early winter. Beginning in early winter, richness climbs sharply through early spring (Table 3). Richness was significant by site (F = 4.9021, p = 0.0019) and by habitat (F = 7.9324, p = 0.0078). More taxa were found in the acequias than in the river (Table 4). The highest richness indices were found at two acequia sites (A1 and A3), followed by two river sites (R1 and R3). A2 and R3 had the lowest richness indices, probably due to being dominated by a single taxa (Amphipoda). Other groups commonly associated with bad water quality, such as Hirudinea and Planaria, were found at all sites except R1. The patterns of presence and absence in the Trichoptera families in the sites show a particularly widespread pattern of distribution, while theHemiptera wereonly collected in the lowest downstream sites of both habitats. EPT indices based on total taxa (richness?) per site were slightly higher at river sites (9, 7, 10) than at acequia sites (9, 5, 7).

Aquatic macroinvertebrate abundance

A total of 27,468 macroinvertebrates was collected over the course of one year of sampling at six sites on eight separate occasions. Two-thirds of all collected macroinvertebrates were from river sites and one third of the total came from acequia sites. From this total we calculated absolute abundance as individuals per m^{-2} .The average abundance at acequia sites ranged from a low of 12 individuals per m^{-2} in spring to 412 in summer, while abundance ranged from 95 per m^{-2} in spring to 524 per m^{-2} in summer at river sites. Differences in taxa abundance by season at all sites was not significant ($F = 0.7268$, $p = 0.5460$); however, patterns of abundance across seasons often followed common patterns determined by life histories (Molles 1985, Jacobi and Benke 1191, Jacobi and Cary 1996).

The highest abundances of benthic aquatic invertebrates at all sites were Ephemeroptera, followed by Trichoptera, Diptera and Crustacea. The high number for Crustacea was the result of R2 being dominated by this order. Two of the acequia sites, both downstream of R2, also had high levels of Crustacea. Ephemeroptera abundance was higher in the acequia sites than in the river sites, while Trichoptera, with the notable exception of Limnephilidae, were considerably more abundant at river sites. There were not higher abundances of Hemiptera in the acequias compared to river sites. Total abundance differences represented as individuals per m^{-2} was not significant by site ($F = 0.7971$, $p = 0.5546$) or by habitat ($F = 2.7143$, $p = 0.1028$). EPT % abundance averages by habitat type were 41% for both acequias (50, 33, and 41 for A1, 2, 3 respectively) and river sites (45, 39, 38) (Table 5).

Community analysis

NMDS produced a two-dimensional solution with a final stress value of 15.04318. Axis 1 represented 27 % of the variation in community data and was positively correlated with flow velocity and dissolved oxygen, while Axis 2 represented 56 % of the variation and was positively correlated with water quality measures (conductivity, salinity and TDS) (Figure 4). Psychodidae (r^2 = -0.085, tau=-0.399), Rhyacophilidae (r^2= 0.182, tau -0.375) and Uenoidae (r ^{2}= 0.093, tau =-0.361) families contributed to the higher water quality found with Axis 2. Amphipoda (r^2 = 0.180, tau = 0.595) was the main contribution to patterns associated with lower water quality. Baetidae (r^2 = -0.374, tau = -0.614), Elmidae (r^2=0.222, tau = -0.480) and Heptageniidae (r^2=0.061, tau = -0.370) influenced Axis 1 river patterns of increased flow and dissolved oxygen. The MRPP results for the invertebrate community data show that all abiotic variables tested had some effect on community structure. Site had the greatest impact (T = -8.14, A = 0.117, p = 0.0000) compared to other categories. The impacts of habitat (T = -0.67, A = -0.010, p = 0.2230) and season (T = 0.00, A = -0.001, p = 0.4778) did not affect community composition. The Mantel Test confirmed the relationship correlations in the MRPP, demonstrating a positive association between the two matrices (r = 0.208, p = 0.0160). Indicator species analysis that seven taxa dominated the patterns we found (Table 6). While all dominated river sites instead of acequia sites, three were stong river indicators (Similiidae, Chronomidae and Hydropsycidae, while three others were weak indictors of acequias (Baetidae, Elmidae, Ephemerellidae). Amphipoda was also found to be an indicator species, but as it dominated sites A2 and R2, its presence on this list is suspect.

DISCUSSION

Overview

Our main goal was to examine aquatic macroinvertebrate patterns between and among the perennial river habitat and the intermittent acequia habitat. We also looked at patterns between sites and between seasons. The only significant difference in these patterns related to richness, and these differences were physically influenced by flow and substrate, both parameters that varied more by site than habitat. This suggests three things: 1) acequias function as IRES, 2) intermediate disturbance in acequias may explain the patterns we see, and 3) acequias in the Mora Valley have an annual flow regime that supports a macroinvertebrate fauna approaching that of a perennial stream in terms of abundance and community composition

General patterns of richness

While we did find some significant differences in water quality measurements between sites, these differences were of a magnitude unlikely to affect macroinvertebrate patterns. Looking at taxa cited as indicators of good water quality, all Ephemeroptera families and two of three Plecoptera families identified were found at all six sites. A third Plecoptera family, the Chloroperlidae, was found at two out of three sites for each habitat (acequia and river). Six Trichoptera families were represented, several which have unique habitat requirements. Rhyacophilidae are thought to be a very pollution sensitive family that was present in overwhelming numbers at the highest (and most pristine) river site, R1. Uenoidae are generally considered a pollution sensitive family generally found only in high coldwater stream, and they were found at all sites except the lowest river site, R3. Brachycentridae are another sensitive family found in the highest and lowest river site (R1 and R3). These free-living caddisflies require a coarse substrate, found at these two sites, but they were also found in the lowest acequia (A3) site, which is mainly sandy substrate. Their distribution therefore is inconsistent with their known habitat preferences in this study. Helicopsychidae are a somewhat pollution tolerant family found mainly in R3 and A3. These caddisflies are adapted to both sandy and/or gravel substrate, and that is what we find at these sites. Hydropsychidae and Limnephilidae are both somewhat pollution tolerant, diverse families found at all sites. From the distribution found at our study sites, one can conclude that the quality of the water in both the river and the acequias appears to be very good. Pollution tolerance information is from Murdoch et al. (1996) and habitat preference is from Voshell (2002).

Impact of flow and substrate on taxa richness

Two parameters appear to have the greatest impact on patterns of richness in our system: 1) flow and 2) substrate. All three acequia sites experienced intermittency over the course of our study due to both drought and local management of the system. The three river sites did not experience interrupted flow; however, a 3.4 km river segment between R2 and R3 was dry throughout the time of our study except for one week in June 2012. The acequias contributed to the valley's hydrological connectivity by creating pathways for flowing water throughout the valley. The only site not impacted by this water diversion is R1, which also had the lowest annual variation of taxa richness for benthic aquatic macroinvertebrates. All other sites had at least twice the variation in taxa richness over the year, suggesting that disturbance from water management in the Mora Valley is affecting seasonal biological richness. When comparing the range in variation of taxa richness between the remaining two river sites and three acequia sites, change throughout the year is only slightly higher in the acequias than in the river. Since all of these sites are perturbed by human management at various times during the year, it may be that seasonal manipulation of both flow and substrate affect taxa richness. In late spring, the acequias were cleaned, a process that requires drying before they are manually raked and cleared of debris. Generally, this results in a swift reduction in fauna right after the cleaning, followed by a slow recovery once flow is restored. In A1, for example, we recorded only 4 taxa after spring cleaning, followed by a steady increase in the number of families until taxa had tripled by mid-summer. This routine, intermediate disturbance could be responsible for the highest richness we found in the acequias. Another possible explanation for the difference in aquatic macroinvertebrate richness between acequia and river sites is substrate size, which is generally more homogenous in the acequias due to manual cleaning of the ditches. Most large rocks are removed to make cleaning of the waterway easier, and collections are silt are loosened so the first flow can wash it downstream. Multiple studies have found substrate to be a factor influencing macroinvertebrate community composition (e.g., Chaves et al. 2011, Hussain and Pandit 2012, Hille et al. 2014, Leslie et al. 2014).

General impact of substrate and flow on invertebrate abundance

While there were significant differences between the river and acequia sites in terms of taxa richness, those differences are well explained by differences in flow velocity and substrate. In many ways, the acequias in this study appear to operate in much the same manner as IRES (Larned et al. 2010, Datry et al. 2014, Datry et al. 2016a, Datry et al. 2016b). The data show patterns of invertebrate abundance and water chemistry that are comparable and not significantly different between the acequias and perennial streams within the same system.

EPT % abundance

Assuming water quality was sufficiently good at all sites for macroinvertebrates, we should have seen greater EPT % abundances at river sites, as presence of all three orders is suggested as an indicator of permanence of flow (Blackburn and Mazzacano 2012).). We did not find this in our study. While EPT % abundance was not significantly different among sites, the most upstream river and acequia sites (R1 and A1), which most closely resemble reference sites, had the highest EPT % abundance, while the middle river and acequia sites (R2 and A2) had the lowest % EPT fauna when compared to other sites. Water is directly diverted from R2 into A2, and Amphipoda dominated these two sites.

Looking at individual families, Ephemeroptera abundance was driven by life history strategies that allow them to be successful. All three families followed generalized patterns found in other studies (Jacobi and Benke, 1991), and they were equally at home in both habitats. Baetidae numbers reflected a multivoltine, cohort asynchronicity, with generally even distribution over all four seasons. Ephemerellidae abundance was highest in winter, then fell off sharply in spring, demonstrating a pattern of a strong winter cohort, univoltine strategy. Heptageniidae families are often univoltine with a dominant winter cohort followed by mixed size distribution, which is what we found. Plecoptera are well adapted to intermittent streams, as they are often small in size, develop rapidly and have a life history that includes diapause during egg and/or larval stages (Jacobi and Cary 1996), along with a clumped distribution. We found less Plecoptera at river sites R2 and R3 than at any acequia site. They can more rapidly recolonize an intermittent stream once it begins to flow again and thus are more resistant to flow disturbances. In contrast, many Trichoptera are dependent on lack of disturbance as their life cycles are relatively long and many are case makers. They are more resistant to drying than Plecoptera, and are very functionally more diverse, filling most functional feeding niches, including those that rely on vegetation for food (Huryn and Wallace 1988). We found more Trichoptera at two river sites (R1 and R3) than at any of the acequia sites. Percentages of various taxa show some distinct differences. If we look at two families of Trichoptera: Limnephilidae, adapted for intermittent waters, and Rhyacophilidae, adapted for perennial flow, we find that Limnephilidae had a strong impact on community composition in our analyses by favoring acequias, while Rhyacophilidae had an extremely high numbers at the only river site where flow was not human impacted, suggesting that these adaptations are important in habitat choice (Bonada et al. 2006) and that resilience is more important to resistance for Trichoptera (Molles 1985).

Community structure

Results from NMDS analysis suggest that aquatic macroinvertebrate community composition differed significantly among sites due to differences in water quality and flow regime. This heterogeneity may be somewhat explained by flow, but we think that differences in water quality measures did not play the key role suggested by our analysis because the differences were not so great as to affect overall water quality for macroinvertebrate habitat. The differences between habitats were not significant and it is possible that the reduction in difference is caused by larger scale parameters such as life history strategies and whole system characteristics not measured in our study. The results from our multivariate analysis support this. Positive associations can be made between families of organisms and their known life history strategies and preferred habitat. We cannot clearly identify which of these traits may have resulted in the patterns we see, because our study was not directly designed to examine the causes of macroinvertebrate patterns. What we can say is that when you look at distribution of macroinvertebrates across habitats, we find there are only minor differences in community composition between acequias and river sites (Figure 4). There are three outlying measurements at some of the acequia sites, which suggests that acequias are more susceptible to perturbation after a disturbance and are not as stable as river sites, but overall community composition in the two habitats are remarkably similar.

Impacts of disturbance and scale on macroinvertebrate patterns

Substrate and flow were determined to be the most important physical parameters affecting richness and abundance among our study sites, as well as biological influences by life history strategies among aquatic macroinvertebrates. These parameters are regulated in our system by the annual cleaning in the acequias and by both natural and human-caused flow variation. Datry et al. (2015) suggest, “Artificially intermittent rivers affected by multiple anthropomorphic stressors will rarely match naturally intermittent rivers in terms of ecological function or biodiversity." Yet we found that our results were much the same as contemporary studies of IRES in that there were differences between the acequias and the river, but those differences were inconsistent. The fact that there were no significant differences in the abundance of benthic invertebrates between river and acequia sites while there were in richness suggests that acequias are perhaps beneficially stressed by moderate human impacts from the annual spring cleaning and regulated flow regimes than their more naturally disturbed river counterparts. Lake (2000) postulates that disruption of flow, through flood, drought, climate change or human impact, creates a perturbation (disturbance + effect) in a stream ecosystem that results in a response from the biota to either withstand the disturbance (resistance) or recover from it (resilience) depending on what effect the intensity and duration of the disturbance has within the system. How the biological community of a stream responds to a disturbance is dependent on both how regularly they occur and how widespread the perturbation is within the community. If the same perturbation occurs with the same annual predictability, the organisms should adapt to that disturbance.

Two major variables in flow-generated disturbance— duration and timing— are controlled in acequias through the community management of the system. The ability of users of the acequias in the Mora Valley to dictate the annual time and duration of drying in an acequia has contributed to the composition of aquatic macroinvertebrate taxa that live in this system. For over a century, these acequias have functioned in much the same manner as types of IRES. The acequias are allowed to dry in late spring and are manually cleaned. Any buildup of organic material in the form of trees, branches, and leaves are physically removed. Eroded channels are rebuilt and sometimes the bottom of the ditch is scoured and silt, clay and large boulders are removed. Any potential flooding during runoff is mitigated by regulating the intake of water from the river, and the cleaning has removed debris that would have been removed had the acequia been allowed to flood. Substrate is kept in place by a lack of flooding, keeping physical patchiness consistent for long periods of time.

On average, acequias in the Mora Valley are dry less than 20% of the time in any given year, with the majority only dry for a few weeks in spring (personal observation). This short drying period may explain why benthic macroinvertebrate richness and abundance in the acequias is so robust. Other studies of IRES have shown that the percentage of time for flow intermittence for a given stream has a direct correlation to benthic invertebrate species richness (Datry et al., 2014). This study is consistent with these findings. Acequias in the Mora Valley not only act like IRES, but due to infrequent annual flow intermittence, they may also function in some ways like perennial streams.

Future directions

We assert that acequias resemble IRES, but more research is needed to determine if our findings are generally applicable to other acequias in northern New Mexico and also longstanding community irrigation ditches around the world. Our research would have benefitted from higher taxonomic resolution, and future studies should make every attempt to identify macroinvertebrates to genus or species. This would allow greater exploration in future studies of the role of life history strategies in the richness, abundance and community patterns of benthic aquatic macroinvertebrates in IRES.

Documenting the management of the acequias and correlating this to the macroinvertebrate data would also allow stronger assertions regarding the seasonal differences we see. The ability to confidently maintain that the ecosystem benefits from the presence of acequias is dependent on further study in these areas.

Conclusions

Acequias show similar patterns of macroinvertebrate richness, abundance, and community structure to those found in IRES. Richness is increased in the acequias compared to the perennial river sites; however, invertebrate abundance is comparable at all sites. Overall patterns are most strongly affected by substrate and flow velocity. Disturbances within acequias, including annual flow intermittence and physical maintenance, are mitigated somewhat by human management. This affects the system in the Mora Valley in such a way that they not only appear to be IRES, but also almost reach perennial stream levels for benthic invertebrate biodiversity. Future research should include higher-level taxonomic identification of macroinvertebrates than we used in our study. This would help determine if specific perturbations or another parameter we did not measure can explain the increased richness we found at acequia sites.

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LITERATURE CITED

Allan, J.D. 1995. Stream Ecology: Structure and Function of Running Waters. Chapman and Hall. London, England.

Arellano, J.E. 2014. Enduring Acequias: Wisdom of the Land, Knowledge of the People. University of New Mexico Press. Albuquerque, New Mexico.

Armstrong, A., R.C. Stedman, J.A. Bishop, and P.J. Sullivan. 2012. What's a stream without water? Disproportionality in headwater regions impacting water quality. Environmental Management 50:849-860.

Arthington, A.H., J.M. Bernardo, and M. Ilheu. 2014. Temporary rivers: linking ecohydrology, ecological quality and reconciliation ecology. River Research and Applications DOI:10.1002/rra.2831.

Blackburn, M. and C. Mazzacano. 2012. Using macroinvertebrates as indication of stream flow duration. The Xerces Society for Invertebrate Conservation. Portland, Oregon.

Bogan, M.T., K.S. Boersma, and D.A. Lytle. 2013. Flow intermittency alters longitudinal patterns of invertebrate diversity and assemblage composition in an arid land stream. Freshwater Biology 58:1016-1028.

Bogan, M.T., K.S. Boersma, and D.A. Lytle. 2015. Resistance and resilience of invertebrate communities to seasonal and supraseasonal drought in arid-land headwater streams. Freshwater Biology 60(12): 2547-2558.

Bonada, N., M. Rieradevall, and N. Prat. 2006. Benthic macroinvertebrate assemblages and macrohabitat connectivity in Mediterranean-climate streams of northern California. Journal of the North American Benthological Society 25(1): 32-43.

Chaves, M.L, P. Rieradevall, J.L. Chainho, M.J. Costa and N. Prat. 2008. Macroinvertebrate communities of non-glacial high altitude intermittent streams. Freshwater Biology 53(1): 55-76.

Datry, T., N. Bonada and A. Boulton. 2016a. Chapter One: General Introduction. Unpublished manuscript.

Datry, T., Fritz, K. and C. Leigh. 2016b. Challenges, developments and perspectives in intermittent river ecology. Freshwater Biology 61:1171-1180.

Datry, T., S.T. Larned, and K. Tockner. 2014. Intermittent rivers: A challenge for freshwater ecology. BioScience 64:229-235.

De Caceres, M., P. Legendre and M. Moretti. 2010. Improving indicator species analysis by combining groups of sites. Okios 119(10):1674-1684.

Eyong, B.E. 2008. Distribution of arsenic and other heavy metals in sediments and their effects on benthic macroinvertebrates in the Gallinas River, San Miguel County, New Mexico. Master’s thesis. New Mexico Highlands University.

Fernald, A.G. and S.J. Guldan. 2006. Surface water-groundwater interactions between irrigation ditches, alluvial aquifers, and streams. Reviews in Fisheries Science 14:79-89.

Fernald, A.G., T.T. Baker, and S.J. Guldan. 2007. Hydrologic, riparian, and agroecosystem functions of traditional acequia irrigation systems. Journal of Sustainable Agriculture 30(2): 147-171.

Hille, S., E.A. Kristensen, D. Graeber, T. Riis, N.K. Jorgensen and A. Baattrup-Pedersen. 2014. Fast reaction of macroinvertebrate communities to stagnation and drought in streams with contrasting nutrient availability. Freshwater Science 33:847-859.

Huryn, A. D. and J.B. Wallace. 1988. Community structure of Trichoptera in a mountain stream: spatial patters of production and functional organization. Freshwater Biology 20:141-155.

Hussain, Q.A. and A.K. Pandit. 2012. Macroinvertebrates in streams: A review of some ecological factors. International Journal of Fisheries and Aquaculture 4:114-123.

Jacobi, D. I. and A.C. Benke. 1991. Life histories and abundance patterns of snag-dwelling mayflies in a blackwater Coastal Plain river. Journal of the North American Benthological Society 10: 372-387.

Jacobi, G.Z. and S.J. Cary. 1996. Winter stoneflies (Plecoptera) in seasonal habitats in New Mexico, USA. Journal of the North American Benthological Society 15:690-699.

Junk, W.J., P.B. Bayley, and R.E. Sparks. 1989. The flood pulse concept in river-floodplain systems. Canadian Special Publications in Aquatic Science 106:110-127.

Kammer, D. 1992. Report on the historic acequia system of the upper Rio Mora. New Mexico Historic Presentation Division.

Lake, P.S. 2000. Disturbance, patchiness and diversity in streams. Journal of the North American Benthological Society. 19:573-592.

Larned, S.T., T. Datry, D.A. Arscott, and K. Tockner. 2010. Emerging concepts in temporary-river ecology. Freshwater Biology 55:717-738.

Leigh, C., A.J. Boulton, J.L. Courtwright, K. Fritz, C.L. May, R.H. Walker, and T. Datry. 2015. Ecological research and management of intermittent rivers: a historical review and future directions. Freshwater Biology 1-19. DOI: 10.1111/fwb12646.

Lenat, D. 1988. Water quality assessment using a qualitative collection method for benthic macroinvertebrates. Journal of the North American Benthological Society 7:222-233.

Leslie, A.W., R.F. Smith, D.E. Ruppert, K. Bejieri, J.M. McGrath, B.A. Needleman and W.O. Lamp. 2012. Environmental factors structuring benthic macroinvertebrate communities of agricultural ditches in Maryland. Environmental Entomology 41:802-812.

Menhinick, E.F. 1964. A comparison of some species-individual diversity indices applied to samples of field insects. Ecology 45(4): 859-861

Merritt, R.W., K.W. Cummins and M.B. Berg. 2008. An Introduction to the Aquatic Insects of North American. Kendall/Hunt, Dubuque, Iowa.

Molles, Jr., M.C. 1985. Recovery of a stream invertebrate community from a flash flood in Tesuque Creek, New Mexico. The Southwestern Naturalist 30: 279-287.

Montgomery, D.R. 1999. Process domains and the river continuum concept. Journal of the American Water Resources Association 35:397-410.

Moore, A.A. and M.A. Palmer. 2005. Invertebrate biodiversity in agricultural and urban headwater streams: Implications for conservation and management. Ecological Applications 15(4):1169-1177.

Muchow, C.L. and J.S. Richardson. 1999. Unexplored diversity: Macroinvertebrates in coastal British Columbia headwater streams. Proceedings of a conference on the Biology and Management of Species and Habitats at Risk, Kamloops, British Columbia, 15-19 Feb 1999, Volume 2:503-506.

Murdoch, T., M. Cheo, and K. O'Laughlin. 1996. Streamkeeper's Field Guide: Watershed Inventory and Stream Monitoring Methods. Adopt-a-Stream Foundation Everett, Washington.

Resh, V.H., M.J. Myers, and M.J. Hannaford. 1996. Macroinvertebrates as biotic indicators of environmental quality. Pages 647-667 in F.R. Hauer and G.A. Lamberti (eds.), Methods in Stream Ecology. Academic Press. San Diego, California.

Rivera, J. A. 1998. Acequia Culture: Water, Land, and Community in the Southwest. University of New Mexico Press, Albuquerque, New Mexico.

Rodriguez, S. 2006. Acequia: Water Sharing, Sanctity, and Place. SAR Press, Santa Fe, New Mexico.

Rufer, M.M. and L.C. Ferrington, Jr. 2006. University of Minnesota Chironomidae Research Group Volunteer Stream Monitoring Interactive Verification Program Website. www.midges.cfans.umn.edu/vsmivp/

Rupert, S.M. 2012. Acequia culture benefits ecosystem function in the Mora Valley. New Mexico Journal of Science Special Water Resources Issue 46:233-248.

Schriever, T.A., M.T. Bogan, K.A. Boersma, M. Caneda-Arguelles, K.L. Jaeger, J.D. Olden and D.A. Lytle. 2015. Hydrology shapes taxonomic and functional structure of desert stream invertebrate communities. Freshwater Science 34: 000-000. DOI: 10.1086/680518.

Stanley, E.M., D.L. Buschman, A.J. Boulton, N.B. Grimm, and S.G. Fisher. 1994. Invertebrate resistance and resilience to intermittency in a desert stream. American Midland Naturalist 131: 288-300.

Thorp, J.H., M.C. Thomas, and M.D. Delong. 2006. The riverine ecosystem synthesis: Biocomplexity in river networks across time and space. River Research Applications 22:123-147.

Vannote, R.L., G.W. Minshall, K.W. Cummins, J.R. Sedell and C.E. Cushing. 1980. The river continuum concept. Canadian Journal of Fisheries and Aquatic Sciences 37:130-137.

Voshell Jr., J.R. 2002. A Guide to Common Freshwater Invertebrates of North American. The MacDonald & Woodward Publishing Company, Granville, Ohio.

Ward, J.V. 1989. The four-dimensional nature of lotic ecosystems. Journal of the North American Benthological Society 8(1):2-8.

Ward, J.V., B.C. Kondratieff and R.E. Zuellig. 2002. An Illustrated Guide to the Mountain Stream Insects of Colorado. University Press of Colorado, Boulder, Colorado.

Williams, D.D. 1996. Environmental constraints in temporary fresh waters and their consequences for the insect fauna. Journal of the North American Benthological Society 15: 634-650.

Figure 1. Map of sampling sites. The highest elevation river site, R1, is on one of the two branched headwater creeks that become the Mora River at the far western end of the Mora Valley in Chacon. It is 16 km upstream before any diversions. The second river site on the Mora River, R2, is directly above the location where water is diverted into the valley's acequias. The third river site on the Mora River, R3, is below both the town of Mora and the 3.4 km stretch where the river is dry much of the year. The first acequia site, A1, has Rio la Casa as its water source, and runs parallel to the second acequia site, A2, which has the Mora River as its source. Both acequias end without directly flowing back into the river. Instead, the water percolates back into the shallow alluvial groundwater over the valley's slopes. The third acequia site, A3, comes off another major acequia and then flows back into the Mora River upstream of R3. *Map credit: Annalea Beattie*

Figure 2. A-F Study Location Images. Photos ordered left to right representing the highest upstream elevation to the lowest elevation in each habitat. A-C: three river sites: R1 (Luna Creek), R2 (Roller Mill), and R3 (Lower Mora). D-F: three acequia sites: A1 (Upper Ditch), A2 (Lower Ditch), and A3 (Valley Ditch).

Figure 3. The NMDS shows that macroinvertebrate community structure at the family level is influenced by flow velocity and dissolved oxygen, which are related, on Axis 1, and conductivity, salinity and TDS, related water quality measures, on Axis 2. These differences in community composition were only significant between sites, while at the habitat level, they are more similar.

Table 1. Study location coordinates, habitat type, and elevation in the Mora River Valley, northern New Mexico. Sites are listed from the highest elevation to lowest elevation.

Site Name (Code)	**UTM Coordinates (NAD 27 CONUS)**	**Habitat Type**	**Elevation (m)**
Luna Creek (R1)	13 S 0468043 4007366	River	2676
Mora River (R2)	13 S 0467565 3982328	River	2234
Upper Ditch (A1)	13 S 0468473 3980541	Acequia	2231
Lower Ditch (A2)	13 S 0468669 3981341	Acequia	2218
Valley Ditch (A3)	13 S 0471821 3981380	Acequia	2188
Mora River (R3)	13 S 0472571 3980604	River	2164

Table 2. Univariate results for physical parameters by site, season and habitat.

PARAMETER	Annual Mean	S.D.	p-values		
			Habitat	Site	Season
Temperature (° C)	11.2	4.40	0.9772	0.8587	<0.0001*
Dissolved oxygen (%)	96.46	13.43	0.9866	0.2428	0.0449*
Conductivity (μScm^{-1})	425.40	143.52	0.6347	<0.0001*	0.0257*
Salinity (ppm)	221	66.15	0.8380	<0.0001*	0.0782
pH	8.65	0.39	0.4051	0.4266	0.0046*
Total Dissolved Solids(mgL^{-1})	304.33	93.78	0.5042	<0.0001*	0.0326*
Wetted channel (cm)	265.62	110.86	<0.0001*	<0.0001*	0.9732
Average depth (cm)	9.97	9.75	0.0694	0.0023*	0.6759
Flow velocity (ms^{-1})	2.34	3.20	0.0035*	<0.0001*	0.6305
Average discharge (m^{3}s^{-1})	0.59	0.60	0.0168*	0.0461*	0.1285

Table 3. Annual summary of physical measures by site. Turbidity was measured as an average of observations, with the clearest water having the lowest value.

Site	R1	R2	R3	A1	A2	A3
Temperature (°C)	9.8	11.9	12.1	10.4	10.5	12.5
DO (%)	85.5	105.9	105.6	92.6	98.7	98.3
Conductivity (μScm^{-1})	257.4	551.5	454.7	207.8	523	528.5
Salinity (ppm)	166.5	275.3	227.1	104.4	261.3	264.2
pH	8.7	8.7	8.7	8.3	8.8	8.5
TDS (mgL^{-1})	193.3	385.7	317.7	147.3	365.4	369.7
Turbidity	0.8	1.8	1.6	0.8	0.7	2
WC (cm)	317.4	411	327.8	102.7	133.8	164
Depth (cm)	14.6	15	14.6	24.3	8	21.5
Flow (ms^{-1})	3	2	1.7	6.4	9.4	2.5
Discharge (m^3s^{-1})	0.9	1.4	1.3	0.8	0.9	0.6

Table 4. Summary of ANOVA results for richness by habitat, site and season. Richness was calculated using Menhinick's Richness Index. The highest the richness value, the greater the richness per equal sample size.

	Mean	S.E.	F	P
HABITAT			7.9324	0.0078*
River	0.64	0.06		
Acequia	0.88	0.06		
SITE			4.9021	0.0019*
R1	0.73	0.09		
R2	0.52	0.09		
R3	0.66	0.09		
A1	1.07	0.10		
A2	0.65	0.87		
A3	1.00	0.09		
SEASON			0.8186	0.5792
Mid-spring	0.77	0.17		
Early summer	0.76	0.14		
Mid-summer	0.80	0.12		
Early fall	0.72	0.12		
Mid-fall	0.62	0.13		
Early winter	0.57	0.14		

Mid-winter	0.83	0.13
Early spring	0.96	0.13

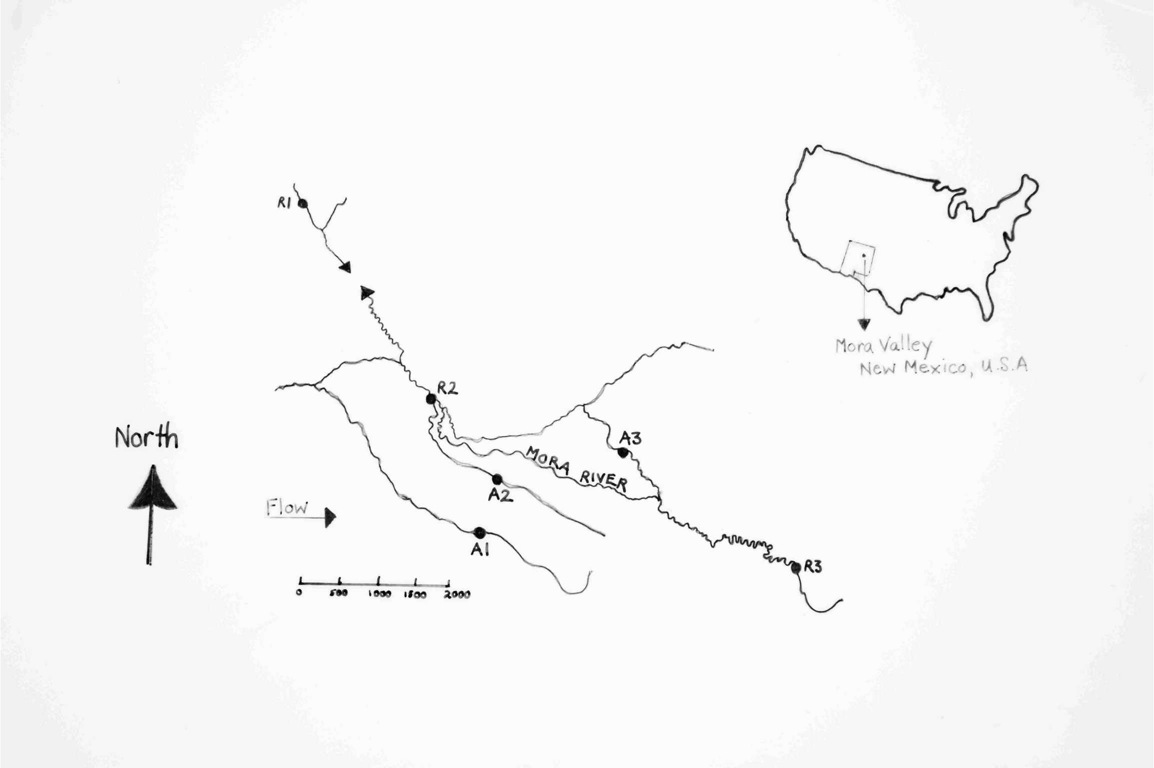
Table 5. Abundance as individuals per m^{-2} by site and (summed?) habitat (acequia versus river).

ORDER	FAMILY	R1	R2	R3	RIVER	A1	A2	A3	ACEQUIA
Ephemeroptera	Baetidae	152	145	308	605	112	458	42	612
	Ephemerellidae	81	31	189	301	6	8	121	135
	Heptageniidae	16	43	15	74	18	4	6	28
Plecoptera	Perlidae	28	1	4	33	29	29	3	61
	Perlodideae	12	10	7	29	6	38	13	57
	Chloroperlidae	38	0	0	38	0	6	17	23
Hemiptera	Naucoridae	0	0	55	55	0	0	25	25
Trichoptera	Hydropsychidae	12	49	262	323	24	25	46	95
	Limnephilidae	16	2	16	34	1	39	6	46
	Rhyacophilidae	42	2	0	44	0	0	0	0
	Brachycentridae	2	0	4	6	0	0	0	0
	Helicopyschidae	0	0	18	18	0	0	1	1
	Uenoidae	113	2	1	116	2	0	0	2
Coleoptera	Elmidae	59	124	86	269	46	147	4	197
	Dytiscadae	0	0	2	2	7	3	0	10
Diptera	Ceratopogonidae	5	0	0	5	0	1	0	1
	Stratiomyidae	2	0	0	2	1	0	0	1

	Chironomidae	40	40	34	114	1	1	8	10
	Ephydridae	7	0	1	8	0	0	0	0
	Ptychopteridae	4	0	0	4	0	0	0	0
	Empididae	32	3	0	35	0	12	0	12
	Simuliidae	3	35	98	136	7	0	1	8
	Psychodidae	145	0	0	145	6	8	0	14
	Tipulidae	3	2	26	31	18	16	4	38
	Tabanidae	9	4	6	19	2	15	1	18
	Muscidae	2	0	0	2	0	14	0	14
Lepidoptera	Pyralidae	0	0	2	2	0	11	0	11
Megaloptera	Corydalidae	0	0	0	0	0	4	0	4
PHYLUM/CLASS	CLASS/ORDER								
Annelida	Oligochaeta	8	8	3	19	2	14	0	16
	Hirudinea	0	0	2	2	0	2	3	5
Platyhelminthes	Planaria	0	1	79	80	1	0	0	1
Gastropoda	Physidae	1	12	11	24	13	0	0	13
Bivalvia	Sphaeriidae	6	2	0	8	0	1	0	1
Crustacaea	Amphipoda	2	392	33	427	0	162	95	257

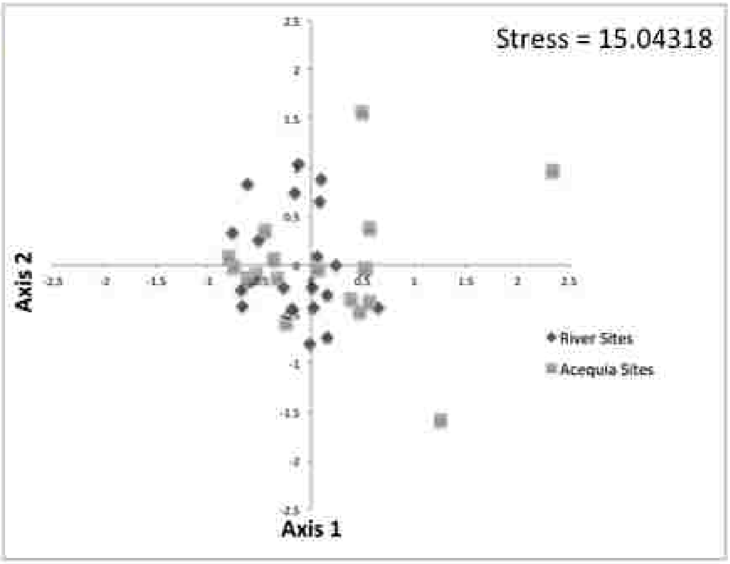
Table 6. Indicator Species Analysis by habitat (river versus acequia). We used an Indicator Values > 50 and a p-value of <0.05 as the cutoff for significance. River and acequia percentages are in the final two columns.

Taxa	IV	p	River	Acequia
Baetidae	72.2	0.0004	75	25
Elmidae	69.7	0.0008	74	26
Hydropsychidae	69.3	0.0004	89	11
Ephemerellidae	60.1	0.0002	83	17
Simuliidae	58.8	0.0002	97	3
Chirnomidae	57.8	0.0002	96	4
Amphipoda	49.9	0.034	76	24


R1
R2
R3
A1
A2
A3
MORA RIVER
North
Flow
0
500
1000
1500
2000
Mora Valley
New Mexico, U.S.A


A
B
C
D
E
F

Increased conductivity↑



Axis 2 represents 56% of variation, influenced by water quality

Decreased conductivity↓

←Greater flow/DO

Less flow/DO→

Axis 1 represents 27% of variation, influenced by flow velocity/DO

NMDS Ordination

SUMMARY

UNDERSTANDING PLACE:

THE ROLE OF PLACE-BASED KNOWLEDGE IN SCIENCE

We need to begin this discussion with a clarification of what place-based knowledge is for the purpose of this project. Place-based knowledge is often confused with or misunderstood as place-based education and traditional ecological knowledge. Place-based knowledge is neither, although the concepts are related. Place-based education is the idea of using what a student knows from their everyday life to teach higher learning concepts. Traditional ecological knowledge is the idea that indigenous peoples pass down an understanding of nature that is as important as what “western science” can teach them. Place-based knowledge is the idea, centered in the social-ecological sciences, that local people have an understanding of their “place” that is complimentary to research done from a global perspective (Fuller 2009, Schoon 2013). With emerging multidisciplinary approaches to environmental issues, place-based knowledge suggests that this local knowledge may clarify, correct or contribute to a formally defined research study or management regime and should not be ignored (Perry 2009, Waterton et al. 2015).

A recurring theme throughout this work is the knowledge of place. Chapter One discusses how local management of acequias, honed over generations of experience by the people who use them, should be acknowledged and integrated into regional and statewide water plans (process). Chapter Two looks at the history of the Mora Valley in terms of land use at the local level (place-based knowledge). Chapter Three looks at how acequias fit into the local ecosystem using macroinvertebrate community structure (patterns).

So often science is conducted disconnected from place (Fuller 2009). There is a reason for this. Science is typically done in a reductionist way. And most ecological studies are still conducted with humans either removed from the system or seen as a variable in the system (Schoon 2013). A single study cannot define a system. I cannot say as much as I would like to be able to say about acequias in the Mora Valley and in other parts of New Mexico. But hopefully, there will be other studies in the future that will look at this same place, but in a different way, until a more complete picture emerges.

I started this project with a single question: Do acequias contribute to overall stream health in the Mora Valley? The question came after I moved to the Mora area and started working with the acequia on my land. I heard stories from my neighbors about *herencia*, their inherited love for the land and their passed-down knowledge of traditional practices. Like most stories, they were part myth and part truth, and I started to wonder if the acequias really did keep the land healthy, as my neighbors insisted.

The definition of river health is not universally agreed upon (Boulton 1999, Karr 1999, Norris and Thoms 1999). It is a mix of ecological ideals and human values (Boulton 1999). For the purpose of this study, we define river health as a stream system's ability to express its capabilities, or in other words, its ability to maintain biotic integrity and stability despite perturbations. While acknowledging that there are other criteria important to river health, we will use Karr's 1999 definition: "Ecological criteria include sustainability, resilience to stress, and ecological integrity—the capacity to maintain a balanced, integrated adaptive biologic system having the full range of elements and processes expected in the natural habitat of a region". Included in this full range of elements are the patterns we see in biological diversity and community structure in the system. The results of my study suggest that the Mora River and the acequias that branch off of it are healthy. They have remained much the same for generations, and should be recognized as intermittent streams. While to me this is good news, affirming the traditional view that acequias enhance health of an ecosystem, many of my neighbors would fear such a statement, because if the acequias somehow become classified as surface water, they could lose their protection to be managed separate from the other surface waters in the state of New Mexico. This would be shortsighted. Future studies should focus closely on the function of the acequias in the ecosystem and their reaction to climate change. These studies should be done at the local level, because generations of local management has created a system, while not stable nor infallible, could provide insight into what we need to keep the system healthy. Only then will we have the complete picture, and it will still be only a snapshot in time.

-Shannon Marie Rupert

"That land is a community is a basic concept of ecology, but that land is to be loved and respected is an extension of ethics."

- Aldo Leopold, *A Sand County Almanac*

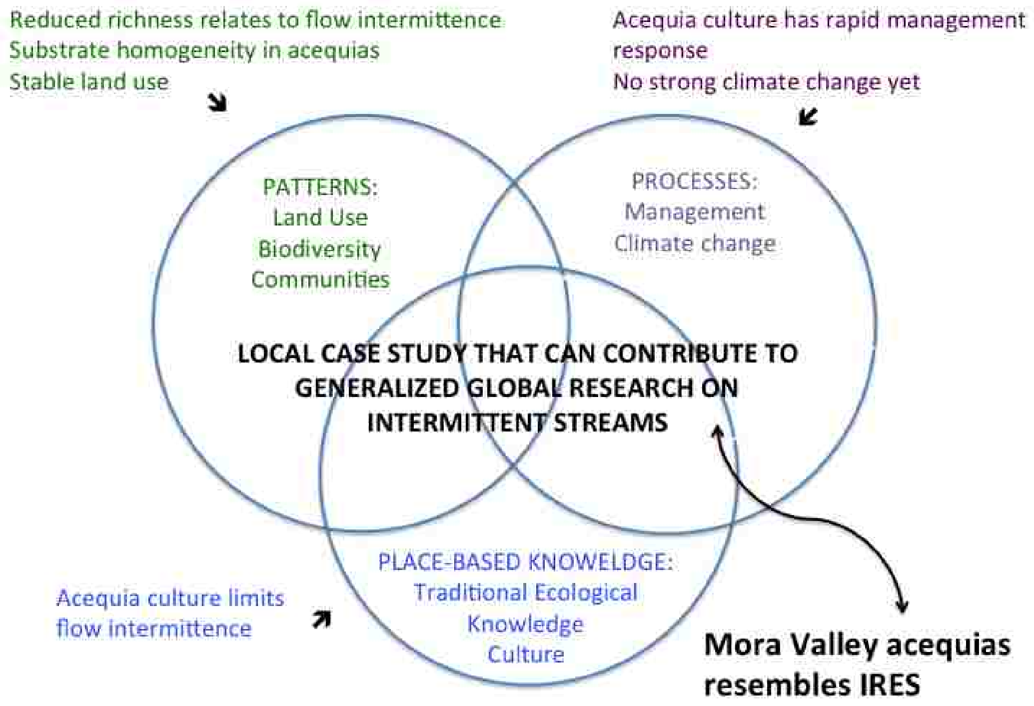


Figure 1. This project combined three integrated investigations to create a local case study applicable for integration in future studies of IRES. We found that substrate homogeneity in acequias and stable land use throughout the study area created a pattern that when combined with the rapid response of acequia culture in limiting flow intermittence in acequias created a local, small scale system where the acequias in the Mora Valley resemble IRES and almost reach the structure of perennial streams.

LITERATURE CITED

Boulton, A.J. 1999. An overview of river health assessment: philosophies, practice, problems and prognosis. Freshwater Biology 41(2): 469-479.

Fuller, B. 2009. Place-based knowledge and consensus building: From access to impact. www.umdcipe.org/conferences/epckdi/22.pdf

Leopold, Aldo. 1966. A Sand County Almanac. Ballentine Books. New Your, New York.

Karr, J.R. 1999. Defining and measuring river health. Freshwater Biology 41(2): 221-234.

Norris, R.H. and M.C. Thoms. 1999. What is river health? Freshwater Biology 41:197-209.

Perry, S.L. 2009. More than one river: Local, place-based knowledge and the political ecology of restoration and remediation along the lower Neponset River, Massachusetts. Dissertations. Paper 117, 226 pgs.

Schoon, M. 2013. Place-based knowledge in a world of globalization. www.michaelschoon.com/2013/04/29/place-based-knowledge-in-a-world-of-globalization/

Waterton, C., Maberly, S.C., Tsouvalis, J., Watson, N., I.J. Winfield and L.R. Norton. 2015. Committing to place: The potential of open collaborations for trusted environmental governance. PLoS Biology 13(3):e1002081.

DISSERTATION LITERATURE CITED

Allen, J.D. 1995. Stream Ecology: Structure and Function of Running Waters. Chapman and Hall. London, England.

Arellano, A.S. 1985. Case Study: Acequias de la Sierra and early agriculture of the Mora Valley. Research Paper. Center for Land Grant Studies. Guadalupita, New Mexico.

Arellano, J.E. 2014. Enduring Acequias: Wisdom of the Land, Knowledge of the People. University of New Mexico Press. Albuquerque, New Mexico.

Armstrong, A., R.C. Stedman, J.A. Bishop, and P.J. Sullivan. 2012. What's a stream without water? Disproportionality in headwater regions impacting water quality. Environmental Management 50(5): 849-860.

Arthington, A.H., J.M. Bernardo, and M. Ilheu. 2014. Temporary rivers: linking ecohydrology, ecological quality and reconciliation ecology. River Research and Applications. DOI:10.1002/rra.2831.

BBC Worldwide Ltd. 2012. Frozen Planet, The Original UK Series, Narrated by David Attenborough. www.bbcearth.com

Bales, R.C., Molotch, N.P., Painter, T.H., Dettinger, M.D, Rice, R., and J. Dozier. 2005. Mountain Hydrology of the Western United States. http://fiesta.bren.ucsb.edu/~dozier/REASoN-pubs/2005WR004387.pdf

Blackburn, M. and C. Mazzacano. 2012. Using macroinvertebrates as indication of stream flow duration. The Xerces Society for Invertebrate Conservation. Portland, Oregon. 17 pages.

Bogan, M.T., K.S. Boersma, and D.A. Lytle. 2013. Flow intermittency alter longitudinal patterns of invertebrate diversity and assemblage composition in an arid land stream. Freshwater Biology 58:1016-1028.

Bogan, M.T., K.S. Boersma, and D.A. Lytle. 2015. Resistance and resilience of invertebrate communities to seasonal and supraseasonal drought in arid-land headwater streams. Freshwater Biology 60: 2547-2558.

Bonada, N., M. Rierradevall, and N. Prat. 2006. Benthic macroinvertebrate assemblages and macrohabitat connectivity in Mediterranean-climate streams of northern California. Journal of the North American Benthological Society 25(1): 32-43.

Boulton, A.J. 1999. An overview of river health assessment: philosophies, practice, problems and prognosis. Freshwater Biology 41(2): 469-479.

Brekhus, J. 2011. Maximum Relief Counties by State. http://www.cohp.org/records/relief/Helman_counties.html

Brickey, C., K. Engel, M.L. Miller, K. Jacobs, D.F. Lueke and B. Udall. 2010. How to Take Climate Change Into Account: A Guidance Document for Judges Adjudicating Water Disputes. Arizona Legal Studies Discussion Paper #10-47. University of Arizona James E. Rogers College of Law.

Carpenter, S.R., Fisher, S.G., Grimm, N.B. and J.F. Kitchell. 1992. Global change and freshwater ecosystems. Annual Review of Ecology and Systematics. 23: 119-139.

Central Arizona Project (CAP) website. 2011. http://www.cap-az.com/

Chaves, M.L, P. Rieradevall, J.L. Chainho, M.J. Costa and N. Prat. 2008. Macroinvertebrate communities of non-glacial high altitude intermittent streams. Freshwater Biology 53 (1): 55-76.

Collins, S.L., S.R. Carpenter, S.M. Swinton, D.E. Orenstein, D.L. Childers, T.L. Gragson, N.B. Grimm, J.M. Grove, S.L. Harlan, J.P. Kaye, A.K. Knapp, G.P. Kofinas, J.J. Magnuson, W.H. McDowell, J.M.Melack, L.A.Ogden, G.P. Robertson, M.D. Smith, and A.C. Whitmer. 2011. An integrated conceptual framework for long-term social ecological research. Frontiers in Ecology and the Environment 9 (6): 352-357.

Cox, M., and J.M. Ross. 2010. Robustness and vulnerability of community irrigation systems: The case of the Taos valley acequias. Journal of Environmental and Economic Management 6 (2011): 254-266.

Cox, M. 2008. Applying a social-ecological system framework to the study of the Taos valley irrigation system. Workshop in Political Theory and Policy Analysis, Indiana University, Bloomington.

D'Antonio, J.R. 2006. The impact of climate change on New Mexico's water supply and ability to manage water resources. New Mexico Office of State Engineer, Santa Fe, New Mexico. www.nmdrought.state.nm.us/ClimateChangeImpacy/completeREPORTfinal.pdf

Datry, T., N. Bonada and A. Boulton. 2016a. Chapter One: General Introduction. Unpublished.

Datry, T., Fritz, K. and C. Leigh. 2016b. Challenges, developments and perspectives in intermittent river ecology. Freshwater Biology 61:1171-1180.

Datry, T., S.T. Larned, and K. Tockner. 2014. Intermittent rivers: A challenge for freshwater ecology. BioScience 64: 229-235.

DeBuys, W. 1985. Enchantment and Exploitation: The Life and Hard Times of a New Mexico Mountain Range. University of New Mexico Press, Albuquerque.

De Caceres, M., P. Legendre and M. Moretti. 2010. Improving indicator species analysis by combining groups of sites. Okios 119(10):1674-1684.

Durance, I. and S.J. Ormerod. 2007. Climate change effects on upland stream macroinvertebrates over a 25-year period. Global Change Biology 13:942-957.

Eyong, B.E. 2008. Distribution of arsenic and other heavy metals in sediments and their effects on benthic macroinvertebrates in the Gallinas River, San Miguel County, New Mexico. Master's thesis. New Mexico Highlands University. 99 pages.

Fernald, A.G., T.T. Baker, and S.J. Guldan. 2007. Hydrologic, riparian, and agroecosystem functions of traditional acequia irrigation systems. Journal of Sustainable Agriculture 30 (2): 147-171.

Fernald, A.G. and S.J. Guldan. 2006. Surface water-groundwater interactions between irrigation ditches, alluvial aquifers, and streams. Reviews in Fisheries Science 14:79-89.

Fuller, B. 2009. Place-based knowledge and consensus building: From access to impact. www.umdcipe.org/conferences/epckdi/22.pdf

Gooch, R.S., P.A. Cherrington, and Y. Reinink. 2007. Salt River Project experience in conversion from agriculture to urban water use. Irrigation and Drainage Systems 21:145–157.

Gutzler, D.S. 2013. Regional climatic considerations for borderlands sustainability. Ecosphere 4(1):7.

Gutzler, D.S. and S.J. Keller. 2012. Observed trends in snowpack and spring season soil moisture affecting New Mexico. New Mexico Journal of Science. 46, pp.

Hanratty, M.P. and H.G. Stefan. 1997. Simulating climate change effects in a Minnesota Agricultural Watershed. Journal of Environmental Quality. 6:1524-1532.

Harding, J.J. 2010. Linking mountains and valleys: exploring the influence of mountain hydrology on traditional acequia irrigation systems. Paper No. 37-1. Geological Society of America Abstracts with Programs, Vol. 42, No. 5, p.111

Hille, S., E.A. Kristensen, D. Graeber, T. Riis, N.K. Jorgensen and A. Baattrup-Pedersen. 2014. Fast reaction of macroinvertebrate communities to stagnation and drought in streams with contrasting nutrient availability. Freshwater Science 33(3): 847-859.

Hoosier Riverwatch. 2009. http://www.in.gov/dnr/nrec/files/nc-Riverwatch_Manual.pdf

Hurd, B.H. and J. Coonrod. Undated. Climate change risks New Mexico's waterways, its byways and its flyways. Water Resources IMPACT 10:4

Huryn, A. D. and J.B. Wallace. 1988. Community structure of Trichoptera in a mountain stream: spatial patters of production and functional organization. Freshwater Biology 20: 141-155.

Hussain, Q.A. and A.K. Pandit. 2012. Macroinvertebrates in streams: A review of some ecological factors. International Journal of Fisheries and Aquaculture 4(7): 114-123.

Jacobi, D.I. and A.C. Benke. 1991. Life histories and abundance patterns of snag-swelling mayflies in a blackwater Coastal Plain river. Journal of the North American Benthological Society 10: 372-387.

Jacobi, G.Z. and S.J. Cary. 1996. Winter stoneflies (Plecoptera) in seasonal habitats in New Mexico, USA. Journal of the North American Benthological Society 15(4): 690-699.

Junk, W.J., P.B. Bayley, and R.E. Sparks. 1989. The flood pulse concept in river-floodplain systems. Canadian Special Publications in Aquatic Science 106:110-127.

Kammer, D. 1992. Report on the historic acequia system of the upper Rio Mora. New Mexico Historic Presentation Division.

Karr, J.R. 1999. Defining and measuring river health. Freshwater Biology 41: 221-234.

Kryder, L.R. 2009. The trans-basin acequias of the Mora Valley, New Mexico: A working paper. Unpublished.

Lake, P.S. 2000. Disturbance, patchiness and diversity in streams. Journal of the North American Benthological Society. 19:573-592.

Lamadrid, E.R. and J.E. Arellano. 2008. Juan the Bear and the Water of Life. University of New Mexico Press, Albuquerque, New Mexico.

Lamadrid, E.R. and J. E. Arellano. 2014. Oral Tradition and Legal Authority in the Trans-Mountain Acequia Systems of the Mora Valley, New Mexico. *From* Sanchis-Ibor, C.; Palau-Salvador, G. Mangue Alférez, I.; Martínez-Sanmartín, L.P. (Eds.) Irrigation, Society, Landscape. Tribute to Thomas F. Glick, València, Universitat Politècnica de València. doi: http://dx.doi.org/10.4995/ISL2014.2014.182

Larned, S.T., T. Datry, D.A. Arscott, and K. Tockner. 2010. Emerging concepts in temporary-river ecology. Freshwater Biology. 55:717-738.

Leigh, C., A.J. Boulton, J.L. Courtwright, K. Fritz, C.L. May, R.H. Walker, and T. Datry. 2015. Ecological research and management of intermittent rivers: a historical review and future directions. Freshwater Biology. 1-19. DOI: 10.1111/fwb12646.

Lenat, D. 1988. Water quality assessment using a qualitative collection method for benthic macroinvertebrates. Journal of the North American Benthological Society 7: 222-233.

Leopold, Aldo. 1966. A Sand County Almanac. Ballentine Books. New York, New York.

Leslie, A.W., R.F. Smith, D.E. Ruppert, K. Bejieri, J.M. McGrath, B.A. Needleman and W.O. Lamp. 2012. Environmental factors structuring benthic macroinvertebrate communities of agricultural ditches in Maryland. Environmental Entomology 41(4): 802-812.

Lindenmayer, D.B. and Fischer, J. 2006. Habitat Fragmentation and Landscape Change: An Ecological and Conservation Synthesis. Island Press, Washington D.C.

Lopez, A. 2014. A bird's-eye view of northern New Mexico's acequias. Green Fire Times 6(1): 7-10.

Lowe, W.H. and G.E. Likens. 2005. Moving headwater streams to the head of the class. BioScience. 55:3, pp 196-197.

MacCameron, R. 1994. Environmental change in colonial New Mexico. Environmental History Review. 18(2):.17-39.

Martinez, F.J. 1990. Mora- San Miguel Regional Water Study and Forty Year Plan. Office of the State Engineer, Santa Fe, New Mexico.

Masse, W.B. 1981. Prehistoric irrigation systems in the Salt River Valley, Arizona. Science. 214 (4519): 408-415.

Menhinick, E.F. 1964. A comparison of some species-individual diversity indices applied to samples of field insects. Ecology 45(4): 859-861.

Merritt, R.W., K.W. Cummins and M.B. Berg. 2008. An Introduction to the Aquatic Insects of North American. Kendall/Hunt, Dubuque, Iowa.

Merritt, R.W and K.W. Cummins. 1996. Trophic relations of macroinvertebrates. In Methods in Stream Ecology. F.R. Hauer and G.A. Lamberti, eds. Academic Press, Inc., San Diego, California. pp: 453-474.

Miller, M.P. and A.M.D. Brasher. 2011. Differences in macroinvertebrate community structure in streams and rivers with different hydrologic regimes in the semi-arid Colorado Plateau. River Systems 19(3): 225-238.

Molles, Jr., M.C. 1985. Recovery of a stream invertebrate community from a flash flood in Tesuque Creek, New Mexico. The Southwestern Naturalist 30: 279-287.

Montgomery, D.R. 1999. Process domains and the river continuum concept. Journal of the American Water Resources Association 35: 397 - 410.

Murdoch, T., M. Cheo, and K. O'Laughlin. 1996. Streamkeeper's Field Guide: Watershed Inventory and Stream Monitoring Methods. Adopt-a-Stream Foundation Everett, Washington.

New Mexico Acequia Association (NMAA). 2008. Acequia Governance Handbook. www.lasacequias.org

New Mexico EPSCoR. 2011. Acequia Research Impacts. http://nmepscor.org/content/acequia-research-impacts

Norris, R.H. and M.C. Thoms. 1999. What is river health? Freshwater Biology 41:197-209.

Peck, D.V., Lazorchak, J.M., and D.J. Klemm (Eds.). 2003. Western Pilot Study: Field Operations Manual for Wadeable Streams (DRAFT). United States Environmental Protection Agency Office of Research and Development, Washington, D.C.

Perry, S.L. 2009. More than one river: Local, place-based knowledge and the political ecology of restoration and remediation along the lower Neponset River, Massachusetts. Dissertations. Paper 117, 226 pgs.

Phillips, D.H., Y. Reinink, T. E. Skarupa, C. E. Ester III and J. A. Skindlov. 2009. Water resources planning and management at the Salt River Project, Arizona, USA. Irrigation and Drainage Systems 23:109–124.

Rango, A. and J. Rivera. 2012. Personal communication.

Resh, V.H., M.J. Myers, and M.J. Hannaford. 1996. Macroinvertebrates as biotic indicators of environmental quality. Pages 647-667 in F.R. Hauer and G.A. Lamberti (eds.), Methods in Stream Ecology. Academic Press. San Diego, California.

Rivera, J. A. 1998. Acequia Culture: Water, Land, and Community in the Southwest. University of New Mexico Press, Albuquerque, New Mexico.

Rivera, J.A. and T.F. Glick. Undated. The Iberian origins of New Mexico's community acequias. www.taosacequias.org/Documents/GlickRivera409.pdf

Roach, W.J., J.B. Heffernen, N.B. Grimm, J. R. Arrowsmith, C. Eisinger, and T. Rychener. 2008. Unintended consequences of urbanization for aquatic ecosystems: A case study from the Arizona desert. Bioscience. 58 (8): 715-727.

Rodriguez, S. 2006. Acequia: Water Sharing, Sanctity, and Place. School for Advanced Research Press, Santa Fe, New Mexico.

Roybal, M. 2012. Measuring Acequia Functionality: Developing a tool for assessing New Mexico's community based irrigation systems. Unpublished Professional Project. University of New Mexico, Albuquerque. 123 pp.

Rufer, M.M. and L.C. Ferrington, Jr. 2006. University of Minnesota Chironomidae Research Group Volunteer Stream Monitoring Interactive Verification Program Website. www.midges.cfans.umn.edu/vsmivp/

Rupert, S.M. 2012. Acequia culture benefits ecosystem function in the Mora Valley. New Mexico Journal of Science Special Water Resources Issue 46:233-248.

Salt River Project website (SRP) 2011. http://www.srpnet.com

Schoon, M. 2013. Place-based knowledge in a world of globalization. www.michaelschoon.com/2013/04/29/place-based-knowledge-in-a-world-of-globalization/

Schriever, T.A., M.T. Bogan, K.A. Boersma, M. Caneda-Arguelles, K.L. Jaeger, J.D. Olden and D.A. Lytle. 2015. Hydrology shapes taxonomic and functional structure of desert stream invertebrate communities. Freshwater Science 34(2): 000-000. DOI: 10.1086/680518.

Shen, W., J. Wu, N. B. Grimm, and D. Hope. 2008. Effects of Urbanization-Induced Environmental Changes on Ecosystem Functioning in the Phoenix Metropolitan Region, USA. Ecosystems 11: 138–155.

Stanley, E.M., D.L. Buschman, A.J. Boulton, N.B. Grimm, and S.G. Fisher. 1994. Invertebrate resistance and resilience to intermittency in a desert stream. American Midland Naturalist 131 (2): 288-300.

State of New Mexico Agency Technical Work Group. 2005. Potential effects of climate change on New Mexico. http://www.nmenv.state.nm.us/aqb/Potential_Effects_Climate_Change.html

Stephens, D.B. and Associates, Inc. 2005. Mora-San Miguel-Guadalupe Regional Water Plan. http://ose.state.nm/isc_regional_plans8.html

Thomson, B. and A-M. Ali. 2009. Water resources assessment of the Mora River. http://hdl.handle.net/1928/9704

Thorp, J.H., M.C. Thomas, and M.D. Delong. 2006. The riverine ecosystem synthesis: Biocomplexity in river networks across time and space. River Research Applications 22:123-147.

United States Department of Agriculture (USDA). 2007. Census of Agriculture: Volume 1: Chapter 2, County Level Data / New Mexico. http://www.agcensus.usda.gov/Publications/2007/Full_Report/Volume_1,_Chapter_2_County_Level/New_Mexico/

United States Geological Survey (USGS). 2012. Water Science for Schools. http://ga.water.usgu.gov/edu/wetstates.html

United States Geological Survey (USGS). 2009. USGS Real-Time Water Data for USA. http://waterdata.usgs.gov/nwis/rt

Vannote, R.L., G.W. Minshall, K.W. Cummins, J.R. Sedell and C.E. Cushing. 1980. The River Continuum Concept. Canadian Journal of Aquatic Science 37:130-137.

Voshell Jr., J.R. 2002. A Guide to Common Freshwater Invertebrates of North American. The MacDonald & Woodward Publishing Company, Granville, Ohio.

Ward, J.V. 1989. The four-dimensional nature of lotic ecosystems. Journal of the North American Benthological Society 8 (1): 2-8.

Ward, J.V., B.C. Kondratieff and R.E. Zuellig. 2002. An Illustrated Guide to the Mountain Stream Insects of Colorado. University Press of Colorado, Boulder, Colorado.

Waterton, C., Maberly, S.C., Tsouvalis, J., Watson, N., I.J. Winfield and L.R. Norton. 2015. Committing to place: The potential of open collaborations for trusted environmental governance. PLoS Biology 13(3):e1002081.

Western Regional Climate Center (WRCC). 2012. http://www.wrcc.dri.edu

Williams, D.D. 1996. Environmental constraints in temporary fresh waters and their consequences for the insect fauna. Journal of the North American Benthological Society 15(4): 634-650.

APPENDIX A

The following is a list of the data points recorded in 2009 in the Mora Valley for the purpose of this study. In addition to recording coordinates in UTM WGS 84 and elevation in meters, each data point was photographed. Digital copies of these photographs are available upon request. Please contact Shannon Rupert.

Photo ID	Elevation	UTM	Easting	Northing
BEVDA2	2189	13 S	470953	3981027
BEVDAM	2195	13 S	470831	3981224
BIGIN	2192	13 S	470906	3981049
BRI030	2176	13 S	472500	3980590
CLEBRG	2255	13 S	466877	3982761
CORDIT	2233	13 S	467802	3982196
CULDRA	2207	13 S	470849	3981157
CULEM	2179	13 S	471471	3980735
D10	2203	13 S	470319	3983018
D11	2210	13 S	470635	3983215
D12	2214	13 S	470779	3983253
D13	2208	13 S	471169	3983276
D14	2210	13 S	471266	3983234
D15	2207	13 S	471256	3983120
DIV	2211	13 S	469595	3982377
DIV007	2216	13 S	470000	3982675
DIV01	2231	13 S	468465	3981811
DIV4	2199	13 S	468990	3981938
DIV8	2214	13 S	470046	3982720
DIV9	2199	13 S	470237	3982938
DRAB4B	2172	13 S	472296	3980765
ELALTO	2169	13 S	472205	3980809
ELCAR	2174	13 S	472340	3980556
MOSPLT	2240	13 S	467798	3982234
RIOCUL	2233	13 S	467793	3981897
RUNIN	2187	13 S	471134	3980923
RUNIN2	2182	13 S	471340	3980822
TWNIN	2208	13 S	470521	3981221

TWNIN2	2203	13 S	470722	3981267
AF1	2196	13 S	470649	3982518
AF10	2189	13 S	470501	3981681
AF11	2185	13 S	470489	3981606
AF2	2190	13 S	470619	3982392
AF3	2195	13 S	470604	3982310
AF4	2187	13 S	470584	3982179
AF5	2191	13 S	470566	3982089
AF6	2188	13 S	470548	3981977
AF7	2188	13 S	470539	3981909
AF8	2190	13 S	470528	3981820
AF9	2190	13 S	470510	3981746
AFEND	2193	13 S	470393	3981385
A1/21	2181	13 S	471822	3981380
ENDPT	2210	13 S	469891	3980068
MAP	2194	13 S	476444	3929243
TW	2197	13 S	470527	3981228
TW2	2198	13 S	470723	3981263
TWBR1	2205	13 S	470852	3981144
UPDBR		13 S	466126	3982181
UPDFA	2282	13 S	466607	3981900
UPDIU		13 S	466004	3982320
UPDIV		13 S	516358	3461707
UPOP1	2259	13 S	466610	3981913
UPOP10	2226	13 S	467087	3981277
UPOP11	2244	13 S	467156	3981187
UPOP12	2249	13 S	466126	3982181
UPOP13	2249	13 S	467258	3981055
UPOP14	2244	13 S	467344	3981033
UPOP15	2240	13 S	467401	3981013
UPOP16	2241	13 S	467469	3980970
UPOP17	2252	13 S	467497	3980951
UPOP18	2240	13 S	467540	3980913
UPOP19	2261	13 S	467604	3980912
UPOP2	2258	13 S	466787	3981793
UPOP20	2217	13 S	467670	3980885
UPOP21	2232	13 S	467663	3980879
UPOP22	2249	13 S	467787	3980830
UPOP23	2114	13 S	467811	3980663
UPOP24	2159	13 S	467924	3980723
UPOP25	2230	13 S	467998	3980738
UPOP26	2232	13 S	468126	3980678
UPOP27	2231	13 S	468250	3980620

UPOP28	2229	13 S	468364	3980590
UPOP29	2228	13 S	468455	3980538
UPOP3	2253	13 S	466815	3981718
UPOP30	2224	13 S	468489	3980556
UPOP31	2225	13 S	468595	3980569
UPOP32	2222	13 S	468803	3980478
UPOP33	2224	13 S	468961	3980350
UPOP34	2225	13 S	469077	3980222
UPOP35	2227	13 S	469320	3980176
UPOP36	2223	13 S	469380	3980183
UPOP37	2223	13 S	469553	3979940
UPOP38	2224	13 S	469878	3979981
UPOP4	2250	13 S	466810	3981647
UPOP5	2255	13 S	466856	3981585
UPOP6	2249	13 S	466869	3981566
UPOP7	2241	13 S	466948	3981481
UPOP8	2251	13 S	467028	3981349
UPOP9	2249	13 S	467084	3981282
UPTNK1	2239	13 S	467299	3981042
UPXING	2261	13 S	466813	3981676
WELL1	2217	13 S	468907	3980415
94	2281	13 S	466032	3982312
434BRG	2195	13 S	470287	3981274
A002 ACEQ	2315	13 S	466977	3977881
ACEINPUT	2204	13 S	469805	3981351
ACESPLIT	2212	13 S	468981	3981677
ALLSRT	2211	13 S	469544	3981378
ALLSUPS	2200	13 S	469548	3981381
CONV	2411	13 S	463615	3989120
DIV1	2225	13 S	468462	3981813
DIV2	2216	13 S	468998	3981946
DIV3	2214	13 S	469029	3981944
DIV4	2217	13 S	469048	3981940
DIV5	2220	13 S	469340	3982191
DIV6	2216	13 S	469589	3982371
DIV7	2213	13 S	469631	3982373
DIV8	2212	13 S	470000	3982668
DIV9	2213	13 S	470045	3982713
DIV10	2210	13 S	470243	3982941
DIV11	2210	13 S	470312	3983015
DIV12	2215	13 S	470631	3983214
DIV13	2210	13 S	470779	3983238
DIV14	2211	13 S	471040	3983292

DIV15	2210	13 S	471152	3983281
DIV16	2210	13 S	471267	3983240
END	2207	13 S	471268	3983239
END2	2208	13 S	471260	3983119
MBCT	2164	13 S	472772	3980286
MBCT DN100	2169	13 S	472773	3980266
MBCT UP100	2172	13 S	472745	3980304
MBCT UP200	2168	13 S	472726	3980323
MORA NMSU	2221	13 S	468647	3981372
MORA WETGR	2212	13 S	468133	3981722
NFHTC DISC	2179	13 S	471672	3981356
NMSU UPPER	2231	13 S	468436	3980539
OFFTRAIL	2217	13 S	468829	3981918
P66	2203	13 S	469677	3981353
P66 MORA R	2210	13 S	469680	3981350
RESCO	2221	13 S	468935	3981932
RLC2	2276	13 S	466511	3982384
RLC3ENDDA1	2248	13 S	467074	3982327
RLCDIV2	2267	13 S	466806	3982411
RLCR1	2295	13 S	466083	3982259
SCHOOLBRG	2203	13 S	469951	3981367
STAGBRIG	2201	13 S	469712	3981341
STRT6-30	2245	13 S	467794	3982232
TEMB ACEQ1	2179	13 S	471818	3981384
UPDICHDIV	2287	13 S	466216	3982270
UPMORADIV	2207	13 S	468060	3981714

APPENDIX B

Additional site information:

Site R1, at Luna Creek, is on USFS Road 17 at the headwaters, used as a baseline, on County Road B001.

Site R2, at the Cleveland Roller Mill, is above the diversion that creates the dry stretch on the river, on County Road B027.

Site, A1, the Upper Ditch, is located on NMSU's John T. Harrington Research Center. This acequia diverts water from Rio la Casa.

Site A2, the Lower Ditch, is also located on NMSU's John T. Harrington Research Center. This acequia diverts water from the Mora River

Site A3, the Valley Ditch, is on County Road A031, in the valley where the most farming occurs. This acequia crosses the road where it has a 90° angle

Site, R3 is on County Road A030, on the east end off Highway 518, just above reservoir and below the bridge.

Physical and Chemical Data (2 pages)

SEASON/ SITE	Temp	DO	Conductivity	Salinity	pH	TDS	Turbidity
MSP-R1	9.3	89.4	210	0	8.2	144	
MSP-R2							
MSP-A1	7.1	91	216	110	7.8	154	
MSP-A2	17.1	101.9	447	224		311	
MSP-A3							
MSP-R3							
ESU-R1	13.1	91.6	135	271	8.7	189	
ESU-R2							
ESU-A1	15.9	99.7	200	101	8.4		
ESU-A2	16.6	104.3	490	245	8.4	343	
ESU-A3							
ESU-R3	15.1	128.8	444	222		310	
MSU-R1	17.5	95.1	297	149		209	C
MSU-R2	16.6	109.8	553	276		387	ST
MSU-A1	13	93.2	198	99		139	C
MSU-A2	15	100.4	535	267	8.7	374	C
MSU-A3	17.8	112	408	204		285	C
MSU-R3	16.9	107.9	424	212		296	C
EF-E1	10.8	58.2	275	137	8.4	192	C
EF-R2	12.7		525	262	8.2	367	C
EF-A1	7.9	86.4	201	100	8.6	140	C
EF-A2	10.2	87.8	496	248	8.6	347	C
EF-A3	15.7		466	233	8.2	326	C
EF-R3	11.2		446	223	8.3	312	C
MF-R1	7.8	93	290	145	8.4	203	C
MF-R2	11.5	102	576	288	8.6	403	ST
MF-A1							
MF-A2	7.4	99.2	547	273	8.8	382	C
MF-A3	11.3	84.6	552	276	8.6	386	M
MF-R3	10.2	85.8	447	223	8.6	312	ST
EW-R1							
EW-R2	5.8		625	312	9.2	437	ST

EW-A1							
EW-A2	1.2		647	323	9.2	452	C
EW-A3	7.6		590	295	8.8	413	M
EW-R3	4.6	100	497	248	9.6	347	M
MW-R1	2.1		299	149	9.1	209	C
MW-R2	9.4		553	276	8.8	387	ST
MW-A1							
MW-A2	6.3		499	249	9.3	349	C
MW-A3	10		625	312	8.5	437	M
MW-R3	10.2		476	238	8.7	333	ST
ESP-R1	7.9		296	148	9.4	207	ST
ESP-R2	15.3		477	238	8.7	333	ST
ESP-A1	8.1		224	112	8.5	156	ST
ESP-A2							
ESP-A3	13.1		530	265	8.5	371	C
ESP-R3	16.5		449	224	8.5	314	ST

Hydrology Data (4 pages)

SEASON/ SITE	Wc-1 (m)	WC-1 (cm)	WC-1(in)	WC-2 (m)	WC-2 (cm)	WC-2(in)	WC-3(m)
MSP-R1	3.556	355.6	140	2.7432	274.32	108	3.3528
MSP-A1	1.7018	170.18	67	1.0668	106.68	42	0.9906
MSP-A2	1.7272	172.72	68	1.9558	195.58	77	1.3208
MSU-R1	3.5052	350.52	138	2.54	254	100	3.2512
MSU-R2	5.2832	528.32	208	4.3688	436.88	172	4.2672
MSU-A1	1.6256	162.56	64	1.2192	121.92	48	1.016
MSU-A2	1.4224	142.24	56	1.651	165.1	65	1.0668
MSU-A3	1.5494	154.94	61	1.4986	149.86	59	1.7272
MSU-R3	3.7084	370.84	146	8.7122	871.22	343	3.3528
EF-R1	2.8448	284.48	112	2.667	266.7	105	3.1496
EF-R2	4.0132	401.32	158	4.1656	416.56	164	3.6576
EF-A1	1.3462	134.62	53	1.1684	116.84	46	0.9906
EF-A2	1.5494	154.94	61	1.3208	132.08	52	1.1176
EF-R3	3.5306	353.06	139	9.1186	911.86	359	3.2766
MF-R1	2.5908	259.08	102	2.5654	256.54	101	2.9718
MF-R2	3.2004	320.04	126	2.667	266.7	105	4.572
MF-A2	1.397	139.7	55	1.778	177.8	70	1.3208
MF-A3	1.6764	167.64	66	1.5494	154.94	61	
MF-R3	3.6576	365.76	144	8.8392	883.92	348	3.2004
MW-R2	2.413	241.3	95	4.3688	436.88	172	4.572
MW-A2	1.651	165.1	65	1.7018	170.18	67	1.2192
MW-A3	2.0828	208.28	82	1.27	127	50	
MW-R3	4.1656	416.56	164	9.4488	944.88	372	3.3782
ESP-R1	3.0734	307.34	121	2.4384	243.84	96	3.1496
ESP-R2	2.2352	223.52	88	3.4544	345.44	136	3.4798
ESP-R3	4.1656	416.56	164	8.9916	899.16	354	3.175

SEASON/ SITE	Wc-3 (cm)	WC-3(in)	AVGD-1(m)	AVGD-1(cm)	AVGD-1(in)	AVGD-2(m)
MSP-R1	335.28	132	0.09398	9.398	3.7	0.11938
MSP-A1	99.06	39	0.20574	20.574	8.1	0.50292
MSP-A2	132.08	52	0.14224	14.224	5.6	0.14732
MSU-R1	325.12	128	0.08382	8.382	3.3	0.0762
MSU-R2	426.72	168	0.3556	35.56	14	0.1905
MSU-A1	101.6	40	0.06096	6.096	2.4	0.1778
MSU-A2	106.68	42	0.06096	6.096	2.4	0.0762
MSU-A3	172.72	68	0.23368	23.368	9.2	0.15494
MSU-R3	335.28	132	0.19558	19.558	7.7	0.12954
EF-R1	314.96	124	0.06604	6.604	2.6	0.06096
EF-R2	365.76	144	0.1397	13.97	5.5	0.1397
EF-A1	99.06	39	0.04318	4.318	1.7	0.15494
EF-A2	111.76	44	0.05588	5.588	2.2	0.06096
EF-R3	327.66	129	0.15748	15.748	6.2	0.10922
MF-R1	297.18	117	0.08382	8.382	3.3	0.07366
MF-R2	457.2	180	0.19304	19.304	7.6	0.11938
MF-A2	132.08	52	0.1016	10.16	4	0.0889
MF-A3			0.1651	16.51	6.5	0.22352
MF-R3	320.04	126	0.24892	24.892	9.8	0.11176
MW-R2	457.2	180	0.17272	17.272	6.8	0.1016
MW-A2	121.92	48	0.07874	7.874	3.1	0.08128
MW-A3			0.09652	9.652	3.8	0.14478
MW-R3	337.82	133	0.26416	26.416	10.4	0.10668
ESP-R1	314.96	124	0.09906	9.906	3.9	0.08382
ESP-R2	347.98	137	0.12954	12.954	5.1	0.07366
ESP-R3	317.5	125	0.2159	21.59	8.5	0.08382

SEASON/ SITE	**AVGD-2(cm)**	**AVGD-2(in)**	**AVGD-3(m)**	**AVGD-3(cm)**	**AVGD-3(in)**	**AVGFLOW(m/s)**
MSP-R1	11.938	4.7	0.20574	20.574	8.1	
MSP-A1	50.292	19.8	0.5334	53.34	21	
MSP-A2	14.732	5.8	0.10922	10.922	4.3	
MSU-R1	7.62	3	0.13208	13.208	5.2	3.4
MSU-R2	19.05	7.5	0.18288	18.288	7.2	1.8
MSU-A1	17.78	7	0.11176	11.176	4.4	6.6
MSU-A2	7.62	3	0.0508	5.08	2	14.4
MSU-A3	15.494	6.1	0.20574	20.574	8.1	3.3
MSU-R3	12.954	5.1	0.18796	18.796	7.4	2.2
EF-R1	6.096	2.4	0.127	12.7	5	2.6
EF-R2	13.97	5.5	0.2413	24.13	9.5	1.9
EF-A1	15.494	6.1	0.12192	12.192	4.8	6.2
EF-A2	6.096	2.4	0.0381	3.81	1.5	9.4
EF-R3	10.922	4.3	0.16256	16.256	6.4	1.3
MF-R1	7.366	2.9	0.12446	12.446	4.9	3.4
MF-R2	11.938	4.7	0.1016	10.16	4	2.2
MF-A2	8.89	3.5	0.1016	10.16	4	3.8
MF-A3	22.352	8.8				2.1
MF-R3	11.176	4.4	0.127	12.7	5	1.5
MW-R2	10.16	4	0.127	12.7	5	2.2
MW-A2	8.128	3.2	0.0635	6.35	2.5	10
MW-A3	14.478	5.7				2.2
MW-R3	10.668	4.2	0.13716	13.716	5.4	1.8
ESP-R1	8.382	3.3	0.14224	14.224	5.6	2.7
ESP-R2	7.366	2.9	0.09652	9.652	3.8	
ESP-R3	8.382	3.3	0.11176	11.176	4.4	1.8

SEASON/ SITE	DISC-1	DISC-2	DISC-3	SUM DISC	AVG DISC
MSU-R1	0.9989399	0.6580632	1.4600228	3.1170260	1.0390087
MSU-R2	3.3816707	1.4980615	1.4046940	6.2844261	2.0948087
MSU-A1	0.6540374	1.4307068	0.7494179	2.8341621	0.9447207
MSU-A2	1.2486169	1.8116093	0.7803855	3.8406117	1.2802039
MSU-A3	1.1948105	0.7662372	1.1726686	3.1337163	1.0445721
MSU-R3	1.5956355	2.4828725	1.3864230	5.4649310	1.8216437
EF-R1	0.4884635	0.4227088	1.0399979	1.9511703	0.6503901
EF-R2	1.0652237	1.1056752	1.6768999	3.8477988	1.2825996
EF-A1	0.3603993	1.1223978	0.7487985	2.2315955	0.7438652
EF-A2	0.8138564	0.7568501	0.4002573	1.9709638	0.6569879
EF-R3	0.7227986	1.2947135	0.6924373	2.7099494	0.9033165
MF-R1	0.7383469	0.6424890	1.2575588	2.6383947	0.8794649
MF-R2	1.3591715	0.7004502	1.0219334	3.0815551	1.0271850
MF-A2	0.5393538	0.6006440	0.5099345	1.6499322	0.5499774
MF-A3	0.5812246	0.7272760	0	1.3085006	0.4361669
MF-R3	1.3656747	1.4818035	0.6096762	3.4571544	1.1523848
MW-R2	0.9169014	0.9765142	1.2774168	3.1708324	1.0569441
MW-A2	1.2999974	1.3832230	0.774192	3.4574124	1.1524708
MW-A3	0.4422701	0.4045153	0	0.8467854	0.2822618
MW-R3	1.9806928	1.8143964	0.8340370	4.6291262	1.5430421
ESP-R1	0.8220177	0.5518441	1.2095976	2.5834595	0.8611531
ESP-R2					
ESP-R3	1.6188354	1.3566166	0.6387084	3.6141605	1.2047202

APPENDIX C:
Aquatic Macroinvertebrate Data

Key for season:

a = Mid-Spring
b = Early Summer
c = Mid-Summer
d = Early Fall
e = Mid-Fall
f = Early Winter
g = Mid-Winter
h = Early Spring

Key for site:

C = R1 = Chacon
ROL = R2 = Roller Mill
UD = A1 =Upper Ditch
LW= A2= Lower Ditch
VL = A3= Valley Ditch
LOW= R3= Lower Mora

Numbers (1, 2, or 3) behind a site are replicate numbers.

Table 1. Baetidae, Ephermerellidae, Heptageniidae, (Ephemeroptera); Perlidae, Perlodidae, (Plecoptera); Corixidae (Hemiptera).

	BAETID	EPHEME	HEPTAG	PERLID	PERLOD	CORIXI
C1a	284	4	0	23	0	0
C2a	245	15	4	19	1	0
C3a	165	11	15	15	0	0
Ca	694	30	19	57	1	0
LD1a	0	0	0	0	0	0
LD2a	1	0	0	0	0	0
Lda	1	0	0	0	0	0
UD1a	3	0	1	0	0	0
UD2a	1	0	0	0	0	0
Uda	4	0	1	0	0	0
C1b	20	83	3	4	13	0
C2b	12	34	0	1	6	0
C3b	13	3	18	0	4	0
Cb	45	120	21	5	23	0
LD1b	209	0	0	0	0	0
LD2b	96	0	2	0	0	0
LDb	305	0	2	0	0	0
UD1b	5	2	35	0	11	0
UD2b	5	5	0	0	0	0
UD3b	280	3	3	0	0	0
Udb	290	10	38	0	11	0
LW1b	32	1	2	0	0	1
LW2b	5	2	0	0	0	0
LW3b	2	2	0	0	0	0
LWb	39	5	2	0	0	1
C1c	36	1	0	7	0	0
C2c	56	1	8	23	0	0
C3c	8	0	1	3	0	0
Cc	100	2	9	33	0	0
RL1c	61	4	1	0	2	0
RL2c	58	0	0	0	0	0
RL3c	143	0	0	0	0	0
RLc	262	4	1	0	2	0
LD1c	205	0	0	8	0	0
LD2c	26	0	5	0	0	0
LD3c	241	0	2	0	5	0
LDc	472	0	7	8	5	0

UD1c	0	0	0	70	6	0
UD2c	0	0	0	0	0	0
UD3c	0	8	3	3	1	1
Udc	0	8	3	73	7	1
VL1c	2	1	0	0	0	0
VL2c	9	10	0	0	0	0
VL3c	22	7	0	0	0	0
VLc	33	18	0	0	0	0
LW1c	1	0	0	0	0	0
LW2c	3	0	0	0	0	0
LW3c	2	3	1	0	0	0
LWc	6	3	1	0	0	0
C1d	5	8	0	28	0	0
C2d	8	0	0	33	9	0
C3d	2	2	0	6	1	0
Cd	15	10	0	67	10	0
RL1d	5	0	0	2	0	0
RL2d	7	0	0	0	0	0
RL3d	17	0	0	0	0	0
RLd	29	0	0	2	0	0
LD1d	0	22	0	27	0	0
LD2d	28	0	0	25	0	0
LD3d	24	2	0	19	0	0
LDd	52	24	0	71	0	0
UD1d	36	0	11	6	0	0
UD2d	2	0	1	2	0	0
UD3d	2	0	1	6	0	0
Udd	40	0	13	14	0	0
VL1d	10	0	0	2	0	0
VL2d	1	0	0	5	0	0
VL3d	2	10	0	1	0	0
VLd	13	10	0	8	0	0
LW1d	24	0	0	15	0	0
LW2d	10	0	0	2	0	0
LW3d	8	0	0	8	0	0
LWd	42	0	0	25	0	0
C1e	51	130	4	3	0	0
C2e	4	0	2	6	0	0
C3e	4	0	12	0	0	0
Ce	59	130	18	9	0	0
RL1e	87	55	0	0	0	0
RL2e	72	0	0	0	0	0
RL3e	34	4	0	0	0	0

Rle	193	59	0	0	0	0
LD1e	37	0	0	2	0	0
LD2e	40	0	2	3	0	0
LD3e	13	0	1	2	0	0
Lde	90	0	3	7	0	0
VL1e	0	0	1	0	0	0
VL2e	0	0	0	0	0	0
Vle	0	0	1	0	0	0
LW1e	12	64	0	0	0	0
LW2e	1	53	0	1	0	0
LW3e	2	2	0	0	0	0
Lwe	15	119	0	1	0	0
RL1f	136	0	69	0	2	0
RL2f	76	25	76	0	26	0
RL3f	169	24	60	0	9	0
RLf	381	49	205	0	37	0
LD1f	0	0	0	0	33	0
LD2f	0	0	0	0	44	0
LD3f	3	0	0	0	14	0
LDf	3	0	0	0	91	0
VL1f	25	37	0	0	0	0
VL2f	3	148	0	0	0	0
VL3f	40	104	1	0	0	0
VLf	68	289	1	0	0	0
LW1f	92	296	12	0	16	0
LW2f	272	160	0	0	0	0
LW3f	404	40	0	0	4	0
LWf	768	496	12	0	20	0
C1g	9	9	0	0	11	0
C2g	3	7	0	0	11	0
C3g	0	15	0	1	2	0
Cg	12	31	0	1	24	0
RL1g	8	15	0	0	1	0
RL2g	0	7	27	0	8	0
RL3g	30	23	32	0	8	0
RLg	38	45	59	0	17	0
LD1g	0	0	0	0	10	0
LD2g	0	0	0	0	6	0
LD3g	0	0	0	0	3	0
LDg	0	0	0	0	19	0
VL1g	0	2	8	0	12	0
VL2g	0	0	6	0	18	0
VL3g	0	11	5	0	2	0

VLg	0	13	19	0	32	0
LW1g	8	98	73	0	5	0
LW2g	135	57	0	0	4	0
LW3g	700	300	0	4	5	0
LWg	843	455	73	4	14	0
C2h	114	106	18	34	1	0
C3h	26	41	9	0	0	0
Ch	140	147	27	34	1	0
RL1h	13	13	0	1	3	0
RL3h	26	12	3	2	0	0
RLh	39	25	3	3	3	0
UD1h	0	0	0	0	0	0
UD2h	0	0	0	0	0	0
UD3h	0	0	0	0	0	0
Udh	0	0	0	0	0	0
VL1h	0	14	0	2	0	0
VL2h	2	17	0	0	5	0
VL3h	0	6	0	0	2	0
VLh	2	37	0	2	7	0
LW1h	64	85	22	0	8	1
LW2h	218	191	20	0	7	0
LW3h	723	304	1	0	5	0
LWh	1005	580	43	0	20	1

Table 2. Naucoridae, Saldidae, (Hemiptera); Hydropsychidae, Limnephilidae, Psychomyiidae, Rhyacophilidae, (Trichoptera)

	NAUCO	**SALIDI**	**HYDROP**	**LIMNEP**	**PSYCHO**	**RHYAC**
C1a	0	0	0	3	0	16
C2a	0	0	0	0	0	13
C3a	0	0	0	0	0	12
Ca	0	0	0	3	0	41
LD1a	0	0	0	8	0	0
LD2a	0	0	0	12	0	0
Lda	0	0	0	20	0	0
UD1a	0	0	9	0	0	0
UD2a	0	0	0	1	0	0
Uda	0	0	9	1	0	0
C1b	0	0	0	10	0	14
C2b	0	0	2	4	0	15
C3b	0	0	0	65	0	7
Cb	0	0	2	79	0	36
LD1b	0	0	0	20	0	0
LD2b	0	0	0	1	0	0
LDb	0	0	0	21	0	0
UD1b	0	0	1	2	0	0
UD2b	0	0	2	0	0	0
UD3b	0	0	1	2	0	0
Udb	0	0	4	4	0	0
LW1b	13	0	37	2	0	0
LW2b	60	0	104	0	0	0
LW3b	26	0	70	0	0	0
LWb	99	0	211	2	0	0
C1c	0	0	0	5	0	39
C2c	0	0	1	0	0	25
C3c	0	0	0	1	0	6
Cc	0	0	1	6	0	70
RL1c	0	0	0	0	0	22
RL2c	0	0	9	0	0	0
RL3c	0	0	13	0	0	0
RLc	0	0	22	0	0	22
LD1c	0	0	0	0	0	0
LD2c	0	0	0	0	0	0
LD3c	0	0	0	0	0	0

LDc	0	0	0	0	0	0
UD1c	0	0	8	0	0	0
UD2c	0	0	0	0	0	0
UD3c	0	0	2	0	0	2
Udc	0	0	10	0	0	2
VL1c	9	0	3	0	0	0
VL2c	4	0	0	0	0	0
VL3c	4	0	0	0	0	0
VLc	17	0	3	0	0	0
LW1c	10	1	4	0	0	0
LW2c	22	0	14	0	0	0
LW3c	43	0	23	1	0	0
LWc	75	1	41	1	0	0
C1d	0	0	8	48	0	0
C2d	0	0	7	23	0	7
C3d	0	0	0	2	0	0
Cd	0	0	15	73	0	7
RL1d	0	0	9	0	0	0
RL2d	0	0	11	0	0	0
RL3d	0	0	13	0	0	0
RLd	0	0	33	0	0	0
LD1d	0	0	15	0	0	2
LD2d	0	0	12	1	0	0
LD3d	0	0	0	0	0	0
LDd	0	0	27	1	0	2
UD1d	0	0	41	0	0	0
UD2d	0	0	0	0	0	0
UD3d	0	0	0	0	0	0
Udd	0	0	41	0	0	0
VL1d	14	0	23	0	0	0
VL2d	14	0	0	0	0	0
VL3d	5	0	2	5	0	0
VLd	33	0	25	5	0	0
LW1d	7	0	13	7	0	0
LW2d	47	0	113	0	0	0
LW3d	28	0	176	6	0	0
LWd	82	0	302	13	0	0
C1e	0	0	34	0	0	59
C2e	0	0	2	0	0	4
C3e	0	0	0	0	0	4
Ce	0	0	36	0	0	67
RL1e	0	0	1	0	0	0
RL2e	0	0	35	0	0	1

RL3e	0	0	9	0	0	0
Rle	0	0	45	0	0	1
LD1e	0	0	8	0	0	0
LD2e	0	0	6	4	0	0
LD3e	0	0	2	4	0	0
Lde	0	0	16	8	0	0
VL1e	0	0	0	0	0	0
VL2e	0	0	0	0	0	0
Vle	0	0	0	0	0	0
LW1e	7	0	14	0	0	0
LW2e	36	0	60	2	0	0
LW3e	34	0	57	18	0	0
Lwe	77	0	131	20	0	0
RL1f	0	0	27	3	0	0
RL2f	0	0	84	2	0	0
RL3f	0	0	48	0	0	0
RLf	0	0	159	5	0	0
LD1f	0	0	22	10	0	0
LD2f	0	0	1	2	0	0
LD3f	0	0	4	7	0	0
LDf	0	0	27	19	0	0
VL1f	4	0	24	2	0	0
VL2f	2	0	3	2	0	0
VL3f	1	0	25	2	0	0
VLf	7	0	52	6	0	0
LW1f	10	0	31	9	0	1
LW2f	11	0	332	10	0	0
LW3f	44	0	441	6	0	0
LWf	65	0	804	25	0	1
C1g	0	0	0	0	0	7
C2g	0	0	4	0	0	10
C3g	0	0	2	0	0	17
Cg	0	0	6	0	0	34
RL1g	0	0	12	1	0	0
RL2g	0	0	18	1	0	0
RL3g	0	0	18	3	0	4
RLg	0	0	48	5	0	4
LD1g	0	0	1	4	0	0
LD2g	0	0	0	3	0	0
LD3g	0	0	5	19	0	0
LDg	0	0	6	26	0	0
VL1g	1	0	3	1	0	0
VL2g	1	0	18	0	0	0

VL3g	2	0	2	0	0	0
VLg	4	0	23	1	0	0
LW1g	0	0	8	2	0	0
LW2g	8	0	41	0	0	0
LW3g	21	0	215	10	0	0
LWg	29	0	264	12	0	0
C2h	0	0	16	0	0	14
C3h	0	0	0	0	0	3
Ch	0	0	16	0	0	17
RL1h	0	0	3	0	0	0
RL3h	0	0	0	0	0	0
RLh	0	0	3	0	0	0
UD1h	0	0	0	1	0	0
UD2h	0	0	0	0	0	0
UD3h	0	0	0	0	0	0
Udh	0	0	0	1	0	0
VL1h	11	0	4	4	0	0
VL2h	5	0	27	3	0	0
VL3h	0	0	4	0	0	0
VLh	16	0	35	7	0	0
LW1h	3	0	16	9	0	0
LW2h	30	0	184	5	0	0
LW3h	30	0	362	22	0	0
LWh	63	0	562	36	0	0

Table 3. Brachycentridae, Polycentropodidae, Helicopsychidae, Uenoidae, (Trichoptera); Elmidae, Hydrophilidae, (Coleoptera)

	BRACHY	POLYCE	HELICO	UENOID	ELMIDA	HPHILI
C1a	0	0	0	14	12	0
C2a	0	0	0	20	11	0
C3a	0	0	0	42	37	0
Ca	0	0	0	76	60	0
LD1a	0	0	0	0	3	0
LD2a	0	0	0	0	2	0
Lda	0	0	0	0	5	0
UD1a	0	0	0	0	0	0
UD2a	0	0	0	0	0	0
Uda	0	0	0	0	0	0
C1b	6	0	0	0	5	0
C2b	4	0	0	0	3	0
C3b	4	0	0	0	8	0
Cb	14	0	0	0	16	0
LD1b	0	0	0	1	2	0
LD2b	0	0	0	0	1	0
LDb	0	0	0	1	3	0
UD1b	0	0	0	2	4	1
UD2b	0	0	0	3	0	1
UD3b	0	0	0	0	9	0
Udb	0	0	0	5	13	2
LW1b	0	0	91	0	4	1
LW2b	8	0	48	0	0	0
LW3b	5	0	8	0	1	0
LWb	13	0	147	0	5	1
C1c	0	0	0	0	5	0
C2c	0	0	0	0	12	0
C3c	0	0	0	1	3	0
Cc	0	0	0	1	20	0
RL1c	0	0	0	0	44	0
RL2c	0	0	0	0	31	0
RL3c	0	0	0	0	29	0
RLc	0	0	0	0	104	0
LD1c	0	0	0	0	63	0
LD2c	0	0	0	0	5	0
LD3c	0	0	0	0	54	0

LDc	0	0	0	0	122	0
UD1c	0	0	0	0	31	0
UD2c	0	0	0	0	0	0
UD3c	0	0	0	0	3	0
Udc	0	0	0	0	34	0
VL1c	0	0	0	0	1	0
VL2c	0	0	0	0	0	0
VL3c	0	0	0	0	0	0
VLc	0	0	0	0	1	0
LW1c	0	0	2	0	1	0
LW2c	0	0	0	0	0	0
LW3c	0	0	2	0	1	0
LWc	0	0	4	0	2	0
C1d	0	0	0	1	1	0
C2d	0	0	0	6	4	0
C3d	0	0	0	40	0	0
Cd	0	0	0	47	5	0
RL1d	0	0	0	0	34	0
RL2d	0	0	0	0	6	0
RL3d	0	0	0	0	7	0
RLd	0	0	0	0	47	0
LD1d	0	0	0	0	15	0
LD2d	0	0	0	0	77	0
LD3d	0	0	0	0	27	0
LDd	0	0	0	0	119	0
UD1d	0	0	0	0	89	0
UD2d	0	0	0	0	2	0
UD3d	0	0	0	0	1	3
Udd	0	0	0	0	92	3
VL1d	0	0	1	1	3	0
VL2d	0	0	0	0	0	0
VL3d	0	0	2	0	0	0
VLd	0	0	3	1	3	0
LW1d	0	0	6	0	10	0
LW2d	0	0	0	0	12	0
LW3d	0	0	1	0	15	0
LWd	0	0	7	0	37	0
C1e	0	0	0	200	139	0
C2e	0	0	0	228	36	0
C3e	0	0	0	131	10	0
Ce	0	0	0	559	185	0
RL1e	0	0	0	1	44	0
RL2e	0	0	0	0	129	0

RL3e	0	0	0	0	6	0
Rle	0	0	0	1	179	0
LD1e	0	0	0	0	33	0
LD2e	0	0	0	0	9	0
LD3e	0	0	0	0	12	0
Lde	0	0	0	0	54	0
VL1e	0	0	0	0	0	0
VL2e	1	0	0	0	0	0
Vle	1	0	0	0	0	0
LW1e	0	0	0	0	15	0
LW2e	0	0	0	0	37	0
LW3e	0	0	3	2	11	0
Lwe	0	0	3	2	63	0
RL1f	0	0	0	1	68	0
RL2f	0	0	0	1	106	0
RL3f	0	0	0	3	114	0
RLf	0	0	0	5	288	0
LD1f	0	0	0	0	47	0
LD2f	0	0	0	0	30	0
LD3f	0	0	0	0	13	0
LDf	0	0	0	0	90	0
VL1f	0	0	0	0	2	0
VL2f	0	0	0	0	1	0
VL3f	0	0	0	0	3	0
VLf	0	0	0	0	6	0
LW1f	0	0	4	1	22	0
LW2f	0	22	0	0	35	0
LW3f	0	60	0	0	70	0
LWf	0	82	4	1	127	0
C1g	0	0	0	11	7	0
C2g	0	0	0	3	14	0
C3g	0	0	0	5	14	0
Cg	0	0	0	19	35	0
RL1g	0	0	0	0	25	0
RL2g	0	0	0	0	24	0
RL3g	0	0	0	0	141	0
RLg	0	0	0	0	190	0
LD1g	0	0	0	0	8	0
LD2g	0	0	0	0	47	0
LD3g	0	0	0	0	2	0
LDg	0	0	0	0	57	0
VL1g	0	0	0	0	0	0
VL2g	0	0	0	0	0	0

VL3g	0	0	0	0	1	0
VLg	0	0	0	0	1	0
LW1g	0	0	0	0	3	0
LW2g	0	0	0	0	1	0
LW3g	0	14	1	0	177	0
LWg	0	14	1	0	181	0
C2h	0	0	0	15	30	0
C3h	0	0	0	9	11	0
Ch	0	0	0	24	41	0
RL1h	0	0	0	0	12	0
RL3h	0	0	0	0	5	0
RLh	0	0	0	0	17	0
UD1h	0	0	0	0	0	0
UD2h	0	0	0	0	0	0
UD3h	0	0	0	0	0	0
Udh	0	0	0	0	0	0
VL1h	0	0	0	0	0	0
VL2h	0	0	0	0	1	0
VL3h	0	0	0	0	2	0
VLh	0	0	0	0	3	0
LW1h	0	0	1	1	42	0
LW2h	0	0	0	0	46	0
LW3h	0	0	0	0	252	0
LWh	0	0	1	1	340	0

Table 4. Dytiscidae, Ceratopogonidae, Stratiomyidae, Chironomidae, Ephydridae, Ptychopteridae (Diptera).

	DYTISC	CERATO	STRATI	CHRONI	EPHYDR	PTYCHO
C1a	0	0	0	0	0	10
C2a	0	0	10	0	0	0
C3a	0	0	5	0	0	19
Ca	0	0	15	0	0	29
LD1a	0	0	0	0	0	0
LD2a	0	0	0	0	0	0
Lda	0	0	0	0	0	0
UD1a	0	0	0	0	0	0
UD2a	0	0	0	0	0	0
Uda	0	0	0	0	0	0
C1b	0	0	0	9	0	0
C2b	0	0	0	3	0	0
C3b	0	0	0	25	0	4
Cb	0	0	0	37	0	4
LD1b	2	0	0	0	0	0
LD2b	3	0	0	0	0	0
LDb	5	0	0	0	0	0
UD1b	2	0	1	0	0	0
UD2b	1	0	0	0	0	0
UD3b	17	0	0	0	0	0
Udb	20	0	1	0	0	0
LW1b	3	0	0	1	0	0
LW2b	0	0	0	0	0	0
LW3b	0	0	0	0	0	0
LWb	3	0	0	1	0	0
C1c	0	0	0	10	0	0
C2c	0	0	0	1	0	0
C3c	0	0	0	50	0	0
Cc	0	0	0	61	0	0
RL1c	0	0	0	1	0	0
RL2c	0	0	0	0	0	0
RL3c	0	0	0	2	0	0
RLc	0	0	0	3	0	0
LD1c	0	0	0	0	0	0
LD2c	0	0	0	0	0	0
LD3c	0	0	0	0	0	0

LDc	0	0	0	0	0	0
UD1c	0	0	0	0	0	0
UD2c	0	0	0	0	0	0
UD3c	0	0	0	1	0	0
Udc	0	0	0	1	0	0
VL1c	0	0	0	0	0	0
VL2c	0	0	0	0	0	0
VL3c	0	0	0	0	0	0
VLc	0	0	0	0	0	0
LW1c	0	0	0	1	0	0
LW2c	0	0	0	0	0	0
LW3c	0	0	0	0	0	0
LWc	0	0	0	1	0	0
C1d	0	14	0	1	0	0
C2d	0	0	0	2	0	0
C3d	0	27	0	0	0	0
Cd	0	41	0	3	0	0
RL1d	0	0	0	0	0	0
RL2d	0	0	0	0	0	0
RL3d	0	0	0	0	0	0
RLd	0	0	0	0	0	0
LD1d	0	0	0	0	0	0
LD2d	0	0	0	0	0	0
LD3d	0	3	0	0	0	0
LDd	0	3	0	0	0	0
UD1d	0	0	0	1	0	0
UD2d	0	0	0	0	0	0
UD3d	0	0	0	1	0	0
Udd	0	0	0	2	0	0
VL1d	0	0	0	0	0	0
VL2d	0	0	0	0	0	0
VL3d	0	0	0	0	0	0
VLd	0	0	0	0	0	0
LW1d	0	0	0	0	0	0
LW2d	0	0	0	0	0	0
LW3d	0	0	0	0	0	0
LWd	0	0	0	0	0	0
C1e	0	0	0	5	0	1
C2e	0	0	0	81	0	0
C3e	0	0	0	11	0	0
Ce	0	0	0	97	0	1
RL1e	0	0	0	7	0	0
RL2e	0	0	0	0	0	0

RL3e	0	0	0	1	0	0
Rle	0	0	0	8	0	0
LD1e	0	0	0	0	0	0
LD2e	0	0	0	0	0	0
LD3e	0	0	0	0	0	0
Lde	0	0	0	0	0	0
VL1e	0	0	0	0	0	0
VL2e	0	0	0	0	0	0
Vle	0	0	0	0	0	0
LW1e	0	0	0	8	0	0
LW2e	0	0	0	18	0	0
LW3e	0	0	0	0	0	0
Lwe	0	0	0	26	0	0
RL1f	0	0	0	12	0	0
RL2f	0	0	0	80	0	0
RL3f	0	0	0	61	0	2
RLf	0	0	0	153	0	2
LD1f	0	0	0	0	1	0
LD2f	0	0	0	0	0	0
LD3f	0	0	0	0	0	0
LDf	0	0	0	0	1	0
VL1f	0	0	0	0	0	0
VL2f	0	0	0	7	0	0
VL3f	0	0	0	16	0	0
VLf	0	0	0	23	0	0
LW1f	1	0	0	48	0	0
LW2f	0	0	0	148	2	0
LW3f	1	0	0	59	5	0
LWf	2	0	0	255	7	0
C1g	0	0	0	0	3	0
C2g	0	0	0	0	9	0
C3g	0	0	0	0	0	0
Cg	0	0	0	0	12	0
RL1g	0	0	0	10	0	0
RL2g	0	0	0	15	0	0
RL3g	0	0	0	59	0	0
RLg	0	0	0	84	0	0
LD1g	0	0	0	1	0	0
LD2g	0	0	0	0	0	0
LD3g	0	0	0	0	0	0
LDg	0	0	0	1	0	0
VL1g	0	0	0	0	0	0
VL2g	0	0	0	0	0	0

VL3g	0	0	0	1	0	0
VLg	0	0	0	1	0	0
LW1g	0	0	0	1	2	0
LW2g	11	0	0	13	0	0
LW3g	7	0	0	7	0	0
LWg	18	0	0	21	2	0
C2h	0	0	0	41	7	0
C3h	0	0	0	6	2	0
Ch	0	0	0	47	9	0
RL1h	0	0	0	2	0	0
RL3h	0	0	0	6	0	0
RLh	0	0	0	8	0	0
UD1h	0	0	0	0	0	0
UD2h	1	0	0	0	0	0
UD3h	0	0	0	0	0	0
Udh	1	0	0	0	0	0
VL1h	0	0	0	0	0	0
VL2h	2	0	0	1	0	0
VL3h	2	0	0	1	0	0
VLh	4	0	0	2	0	0
LW1h	0	0	0	0	0	0
LW2h	18	0	0	0	4	0
LW3h	38	0	0	0	0	0
LWh	56	0	0	0	4	0

Table 5. Empididae, Simuliidae, Psychodidae, Tipulidae, Tabanidae, Muscidae (Diptera)

	EMPIDI	**SIMULI**	**PSDIDA**	**TIPULI**	**TABANI**	**MUSCID**
C1a	7	0	0	0	0	5
C2a	0	3	0	0	0	3
C3a	18	0	0	0	0	5
Ca	25	3	0	0	0	13
LD1a	0	0	10	0	0	19
LD2a	0	0	6	0	0	9
Lda	0	0	16	0	0	28
UD1a	0	0	7	0	0	0
UD2a	0	0	5	0	0	0
Uda	0	0	12	0	0	0
C1b	0	0	0	2	28	0
C2b	0	0	0	4	11	0
C3b	0	0	0	3	4	0
Cb	0	0	0	9	43	0
LD1b	0	0	0	2	2	0
LD2b	0	0	0	2	1	1
LDb	0	0	0	4	3	1
UD1b	0	0	0	11	0	0
UD2b	0	0	0	1	0	0
UD3b	0	0	0	9	7	0
Udb	0	0	0	21	7	0
LW1b	0	0	0	15	3	0
LW2b	0	0	3	33	0	0
LW3b	0	0	0	22	0	0
LWb	0	0	3	70	3	0
C1c	0	0	0	0	0	0
C2c	0	0	4	2	0	0
C3c	0	1	0	0	0	0
Cc	0	1	4	2	0	0
RL1c	0	1	0	0	0	0
RL2c	0	75	0	0	0	0
RL3c	0	47	0	0	0	0
RLc	0	123	0	0	0	0
LD1c	0	1	0	0	1	0

LD2c	0	0	0	0	0	0
LD3c	0	0	0	0	0	0
LDc	0	1	0	0	1	0
UD1c	0	13	0	12	0	0
UD2c	0	0	0	3	0	0
UD3c	0	1	0	13	0	0
Udc	0	14	0	28	0	0
VL1c	0	1	0	3	0	0
VL2c	0	3	0	0	0	0
VL3c	0	0	0	0	0	0
VLc	0	4	0	3	0	0
LW1c	0	4	0	2	1	0
LW2c	0	2	0	0	0	0
LW3c	0	9	0	0	0	0
LWc	0	15	0	2	1	0
C1d	0	0	0	0	7	0
C2d	2	2	0	0	0	0
C3d	0	0	0	0	0	0
Cd	2	2	0	0	7	0
RL1d	0	0	0	0	0	0
RL2d	0	0	0	0	0	0
RL3d	0	2	0	0	0	0
RLd	0	2	0	0	0	0
LD1d	0	1	0	4	0	0
LD2d	0	0	0	0	0	0
LD3d	0	0	0	0	0	0
LDd	0	1	0	4	0	0
UD1d	0	5	0	0	0	0
UD2d	0	0	0	2	0	0
UD3d	0	0	0	4	0	0
Udd	0	5	0	6	0	0
VL1d	0	0	0	0	0	0
VL2d	0	1	0	1	0	0
VL3d	0	0	0	0	0	0
VLd	0	1	0	1	0	0
LW1d	0	3	0	3	0	0
LW2d	0	2	0	0	0	0
LW3d	0	3	0	0	0	0
LWd	0	8	0	3	0	0
C1e	4	0	582	0	0	0
C2e	11	3	165	0	0	0
C3e	4	0	289	0	3	0
Ce	19	3	1036	0	3	0

RL1e	6	2	0	0	0	0
RL2e	0	36	0	0	0	0
RL3e	6	8	0	0	0	0
Rle	12	46	0	0	0	0
LD1e	0	0	0	4	7	0
LD2e	0	0	0	18	0	0
LD3e	33	0	0	6	0	0
Lde	33	0	0	28	7	0
VL1e	0	0	0	0	0	0
VL2e	0	0	0	0	0	0
Vle	0	0	0	0	0	0
LW1e	0	168	0	1	21	0
LW2e	0	89	0	0	12	0
LW3e	0	20	0	0	2	0
Lwe	0	277	0	1	35	0
RL1f	0	17	0	1	6	0
RL2f	0	28	0	0	9	0
RL3f	0	27	0	2	2	0
RLf	0	72	0	3	17	0
LD1f	1	0	0	5	0	0
LD2f	0	0	0	5	0	0
LD3f	0	0	0	2	0	0
LDf	1	0	0	12	0	0
VL1f	0	0	0	2	0	0
VL2f	0	0	1	0	0	0
VL3f	1	0	0	3	0	0
VLf	1	0	1	5	0	0
LW1f	0	231	0	8	7	0
LW2f	0	60	1	23	0	0
LW3f	0	212	0	15	0	0
LWf	0	503	1	46	7	0
C1g	2	0	4	0	1	0
C2g	0	0	5	0	0	0
C3g	5	1	4	0	0	0
Cg	7	1	13	0	1	0
RL1g	1	0	0	0	2	0
RL2g	0	6	0	2	3	0
RL3g	0	12	0	5	0	0
RLg	1	18	0	7	5	0
LD1g	4	0	0	0	8	0
LD2g	0	0	0	0	9	0
LD3g	0	0	0	0	15	0
LDg	4	0	0	0	32	0

VL1g	0	0	0	0	0	0
VL2g	0	0	0	0	3	0
VL3g	0	0	0	3	1	0
VLg	0	0	0	3	4	0
LW1g	0	34	0	18	0	0
LW2g	2	3	1	28	0	0
LW3g	1	30	0	15	0	0
LWg	3	67	1	61	0	0
C2h	86	4	0	2	10	0
C3h	3	0	1	4	1	0
Ch	89	4	1	6	11	0
RL1h	0	0	0	0	0	0
RL3h	0	1	0	2	0	0
RLh	0	1	0	2	0	0
UD1h	0	0	0	0	0	0
UD2h	0	0	0	0	0	0
UD3h	0	0	0	0	0	0
Udh	0	0	0	0	0	0
VL1h	0	0	0	2	0	0
VL2h	0	0	0	0	0	0
VL3h	0	0	0	0	0	0
VLh	0	0	0	2	0	0
LW1h	0	1	0	8	0	0
LW2h	0	0	0	21	0	0
LW3h	1	0	0	17	0	1
LWh	1	1	0	46	0	1

Table 6. Oligochaeta, Hirudinea, (Annelida); Planaria (Platyhelminthes); Physidae, Planoribidae, Lymnaeidae, (Gastropoda)

	OLIGOC	**HIRUDI**	**PLANAR**	**PHYSID**	**PLANOR**	**LYMNA**
C1a	0	0	0	0	0	0
C2a	0	0	0	1	0	1
C3a	0	0	0	2	0	6
Ca	0	0	0	3	0	7
LD1a	0	0	0	0	0	0
LD2a	0	0	0	0	0	0
Lda	0	0	0	0	0	0
UD1a	0	0	2	0	0	0
UD2a	0	0	0	0	0	0
Uda	0	0	2	0	0	0
C1b	3	0	0	0	0	0
C2b	10	0	0	0	0	0
C3b	2	0	0	0	0	0
Cb	15	0	0	0	0	0
LD1b	6	0	0	0	0	0
LD2b	0	2	0	0	0	0
LDb	6	2	0	0	0	0
UD1b	0	0	0	0	0	0
UD2b	0	0	0	4	0	0
UD3b	6	2	0	7	0	0
Udb	6	2	0	11	0	0
LW1b	7	0	50	12	0	0
LW2b	11	0	63	7	0	0
LW3b	3	0	9	2	0	0
LWb	21	0	122	21	0	0
C1c	2	0	0	0	0	0
C2c	7	0	0	0	0	0
C3c	0	0	0	0	0	0
Cc	9	0	0	0	0	0
RL1c	6	1	0	4	0	0
RL2c	22	1	0	1	0	0
RL3c	4	0	0	1	0	0
RLc	32	2	0	6	0	0

LD1c	2	0	0	0	0	0
LD2c	0	1	0	0	0	0
LD3c	0	1	0	0	0	0
LDc	2	2	0	0	0	0
UD1c	0	0	0	1	0	0
UD2c	1	0	0	5	0	0
UD3c	0	0	0	1	0	0
Udc	1	0	0	7	0	0
VL1c	0	0	0	0	0	0
VL2c	0	0	0	0	0	0
VL3c	0	1	1	0	0	0
VLc	0	1	1	0	0	0
LW1c	4	1	25	3	0	0
LW2c	0	1	33	4	0	0
LW3c	1	5	28	5	0	0
LWc	5	7	86	12	0	0
C1d	8	0	0	0	0	0
C2d	3	0	0	0	0	0
C3d	0	0	0	0	1	0
Cd	11	0	0	0	1	0
RL1d	1	1	0	0	0	0
RL2d	5	0	0	0	0	0
RL3d	5	0	0	0	0	0
RLd	11	1	0	0	0	0
LD1d	4	2	0	0	0	0
LD2d	2	0	0	0	0	0
LD3d	3	0	0	0	0	0
LDd	9	2	0	0	0	0
UD1d	0	0	0	11	0	0
UD2d	0	0	0	1	0	0
UD3d	1	0	0	14	0	0
Udd	1	0	0	26	0	0
VL1d	0	0	0	0	0	0
VL2d	0	0	0	1	0	0
VL3d	0	1	0	0	0	0
VLd	0	1	0	1	0	0
LW1d	1	2	46	5	0	0
LW2d	0	0	49	0	0	0
LW3d	0	3	13	0	0	0
LWd	1	5	108	5	0	0
C1e	2	0	0	1	0	0
C2e	0	0	0	0	0	0
C3e	0	0	0	0	0	0

Ce	2	0	0	1	0	0
RL1e	2	0	0	7	0	0
RL2e	0	0	0	24	0	0
RL3e	0	0	0	3	0	0
Rle	2	0	0	34	0	0
LD1e	7	0	0	0	0	0
LD2e	2	1	0	0	0	0
LD3e	10	3	0	0	0	0
Lde	19	4	0	0	0	0
VL1e	0	0	0	0	0	0
VL2e	0	0	0	0	0	0
Vle	0	0	0	0	0	0
LW1e	0	1	13	4	0	0
LW2e	0	0	106	9	0	0
LW3e	0	1	43	4	0	0
Lwe	0	2	162	17	0	0
RL1f	3	0	3	10	0	0
RL2f	0	0	3	10	0	2
RL3f	2	0	0	10	0	0
RLf	5	0	6	30	0	2
LD1f	0	0	0	1	0	0
LD2f	0	0	0	0	0	0
LD3f	1	0	0	0	0	0
LDf	1	0	0	1	0	0
VL1f	0	0	0	0	1	0
VL2f	0	2	0	0	0	0
VL3f	0	1	0	0	1	1
VLf	0	3	0	0	2	1
LW1f	0	1	23	4	1	0
LW2f	1	0	82	2	0	0
LW3f	0	1	46	13	0	0
LWf	1	2	151	19	1	0
C1g	1	0	0	0	0	0
C2g	4	0	0	0	0	0
C3g	0	0	0	0	0	0
Cg	5	0	0	0	0	0
RL1g	1	0	1	0	0	0
RL2g	1	1	0	0	0	0
RL3g	3	0	3	0	0	0
RLg	5	1	4	0	0	0
LD1g	1	0	0	2	0	0
LD2g	2	2	2	0	0	0
LD3g	2	0	0	0	0	0

LDg	5	2	2	2	0	0
VL1g	0	0	0	0	0	0
VL2g	0	0	0	0	0	0
VL3g	0	0	1	1	0	0
VLg	0	0	1	1	0	0
LW1g	1	3	11	0	0	0
LW2g	1	0	13	0	0	0
LW3g	1	0	0	0	0	0
LWg	3	3	24	0	0	0
C2h	4	0	0	0	0	0
C3h	1	0	0	1	0	0
Ch	5	0	0	1	0	0
RL1h	0	0	0	0	0	0
RL3h	0	0	0	1	0	0
RLh	0	0	0	1	0	0
UD1h	0	0	1	1	0	0
UD2h	0	0	1	0	0	0
UD3h	0	0	0	1	0	0
Udh	0	0	2	2	0	0
VL1h	0	2	0	0	0	0
VL2h	0	0	0	0	0	0
VL3h	1	0	0	0	0	0
VLh	1	2	0	0	0	0
LW1h	0	1	19	1	0	0
LW2h	2	0	9	2	0	0
LW3h	2	0	0	2	0	0
LWh	4	1	28	5	0	0

Table 7. Sphaeriidae (Bivalva); Amphipoda (Crustacea); Gomphidae, Aeshnidae, (Odonata); Isopoda (Isopoda); Pyralidae (Lepodoptera)

	SPHAER	AMPHIP	GOMPHI	AESHNI	ISOPOD	PYRALI
C1a	0	0	0	0	0	0
C2a	0	0	0	0	0	0
C3a	0	0	0	0	0	0
Ca	0	0	0	0	0	0
LD1a	2	0	0	0	0	0
LD2a	0	0	0	0	0	0
Lda	2	0	0	0	0	0
UD1a	0	0	0	0	0	0
UD2a	0	0	0	0	0	0
Uda	0	0	0	0	0	0
C1b	0	0	0	0	0	0
C2b	2	0	0	0	0	0
C3b	4	0	0	0	0	0
Cb	6	0	0	0	0	0
LD1b	0	7	0	0	0	0
LD2b	0	0	0	0	0	0
LDb	0	7	0	0	0	0
UD1b	0	0	0	0	0	0
UD2b	0	0	0	0	0	0
UD3b	0	1	0	0	1	0
Udb	0	1	0	0	1	0
LW1b	0	84	1	0	0	0
LW2b	2	0	0	0	0	8
LW3b	0	1	0	0	0	0
LWb	2	85	1	0	0	8
C1c	0	0	0	0	0	0
C2c	5	0	0	0	0	0
C3c	0	0				
Cc	5	0	0	0	0	0
RL1c	0	201	0	0	0	0
RL2c	0	269	0	0	0	0
RL3c	0	675	0	0	0	0
RLc	0	1145	0	0	0	0

LD1c	0	33	0	0	0	0
LD2c	0	35	0	0	0	0
LD3c	0	9	0	0	0	0
LDc	0	77	0	0	0	0
UD1c	0	0	0	0	0	0
UD2c	0	0	0	0	0	0
UD3c	0	0	0	0	0	0
Udc	0	0	0	0	0	0
VL1c	0	0	0	0	0	0
VL2c	0	0	1	0	0	0
VL3c	0	1	0	0	0	0
VLc	0	1	1	0	0	0
LW1c	0	7	1	0	0	0
LW2c	0	4	0	0	0	0
LW3c	0	13	0	0	0	0
LWc	0	24	1	0	0	0
C1d	0	0	0	0	0	0
C2d	0	0	0	0	0	0
C3d	0	0	0	0	0	0
Cd	0	0	0	0	0	0
RL1d	0	237	0	0	0	0
RL2d	0	143	0	0	0	0
RL3d	0	232	0	0	0	0
RLd	0	612	0	0	0	0
LD1d	0	41	0	0	0	0
LD2d	0	54	0	0	0	0
LD3d	0	16	0	0	0	0
LDd	0	111	0	0	0	0
UD1d	0	0	0	0	0	0
UD2d	0	0	0	0	0	0
UD3d	0	0	0	1	0	0
Udd	0	0	0	1	0	0
VL1d	0	3	0	0	0	0
VL2d	0	43	0	0	0	0
VL3d	0	16	0	0	0	0
VLd	0	62	0	0	0	0
LW1d	0	14	0	0	0	1
LW2d	0	1	1	0	0	1
LW3d	0	20	0	0	0	0
LWd	0	35	1	0	0	2
C1e	10	0	0	0	0	1
C2e	0	0	0	0	0	0
C3e	5	0	0	0	0	0

Ce	15	0	0	0	0	1
RL1e	1	262	0	0	0	0
RL2e	0	116	0	0	0	0
RL3e	0	16	0	0	0	0
Rle	1	394	0	0	0	0
LD1e	0	87	0	0	0	0
LD2e	0	20	0	0	0	0
LD3e	1	19	0	0	0	0
Lde	1	126	0	0	0	0
VL1e	0	3	0	0	0	0
VL2e	0	5	0	0	0	0
Vle	0	8	0	0	0	0
LW1e	0	6	0	0	0	0
LW2e	0	5	0	0	0	4
LW3e	0	9	0	0	0	1
Lwe	0	20	0	0	0	5
RL1f	0	78	0	0	0	0
RL2f	0	50	0	0	0	0
RL3f	0	91	0	0	0	0
RLf	0	219	0	0	0	0
LD1f	0	50	0	0	0	0
LD2f	0	2	0	0	0	0
LD3f	0	2	0	0	0	0
LDf	0	54	0	0	0	0
VL1f	1	8	0	0	0	0
VL2f	0	30	0	0	0	0
VL3f	1	33	0	0	0	0
VLf	2	71	0	0	0	0
LW1f	0	34	0	0	0	0
LW2f	0	8	0	0	0	2
LW3f	0	44	0	0	0	2
LWf	0	86	0	0	0	4
C1g	0	0	0	0	0	0
C2g	2	0	0	0	0	0
C3g	0	0	0	0	0	0
Cg	2	0	0	0	0	0
RL1g	0	78	0	0	0	0
RL2g	0	53	0	0	0	0
RL3g	5	122	0	0	0	0
RLg	5	253	0	0	0	0
LD1g	0	79	0	0	0	0
LD2g	1	50	0	0	0	0
LD3g	1	8	0	0	0	0

LDg	2	137	0	0	0	0
VL1g	0	5	0	0	0	0
VL2g	0	0	0	0	0	0
VL3g	0	5	0	0	0	0
VLg	0	10	0	0	0	0
LW1g	1	9	0	0	0	0
LW2g	0	11	0	0	0	2
LW3g	1	2	0	0	0	8
LWg	2	22	0	0	0	10
C2h	0	5	0	0	0	0
C3h	0	0	0	0	0	0
Ch	0	5	0	0	0	0
RL1h	0	9	0	0	0	0
RL3h	0	36	0	0	0	0
RLh	0	45	0	0	0	0
UD1h	0	0	0	0	0	0
UD2h	0	0	0	0	0	0
UD3h	0	0	0	0	0	0
Udh	0	0	0	0	0	0
VL1h	0	32	0	0	0	0
VL2h	0	38	0	0	0	0
VL3h	0	59	0	0	0	0
VLh	0	129	0	0	0	0
LW1h	0	5	0	0	0	0
LW2h	0	2	0	0	0	9
LW3h	1	1	1	0	0	13
LWh	1	8	1	0	0	22

Table 8. Corydalidae (Megaloptera); Hydracarina (Hydracarina); Chloroperlidae (Plecoptera)

	CORYDA	HYDRAC	CHLORO
C1a	0	0	0
C2a	0	0	0
C3a	0	0	0
Ca	0	0	0
LD1a	0	0	0
LD2a	0	0	0
Lda	0	0	0
UD1a	0	0	0
UD2a	0	0	0
Uda	0	0	0
C1b	0	0	0
C2b	0	0	0
C3b	0	0	0
Cb	0	0	0
LD1b	0	0	0
LD2b	0	0	0
LDb	0	0	0
UD1b	0	0	0
UD2b	0	0	0
UD3b	0	0	0
Udb	0	0	0
LW1b	0	0	0
LW2b	0	0	0
LW3b	0	0	0
LWb	0	0	0
C1c	0	0	0
C2c	0	0	0
C3c			
Cc	0	0	0
RL1c	0	0	0
RL2c	0	0	0
RL3c	0	0	0
RLc	0	0	0

LD1c	0	0	0
LD2c	0	0	0
LD3c	0	0	0
LDc	0	0	0
UD1c	0	0	0
UD2c	0	0	0
UD3c	0	0	0
Udc	0	0	0
VL1c	0	0	0
VL2c	0	0	0
VL3c	0	0	0
VLc	0	0	0
LW1c	0	0	0
LW2c	0	0	0
LW3c	0	0	0
LWc	0	0	0
C1d	0	0	0
C2d	0	0	0
C3d	0	0	0
Cd	0	0	0
RL1d	0	0	0
RL2d	0	0	0
RL3d	0	0	0
RLd	0	0	0
LD1d	0	0	0
LD2d	1	0	0
LD3d	0	0	0
LDd	1	0	0
UD1d	0	0	0
UD2d	0	0	0
UD3d	0	0	0
Udd	0	0	0
VL1d	0	0	0
VL2d	0	0	0
VL3d	0	0	0
VLd	0	0	0
LW1d	0	0	0
LW2d	0	0	0
LW3d	0	0	0
LWd	0	0	0
C1e	0	0	56
C2e	0	0	138
C3e	0	0	13

Ce	0	0	207
RL1e	0	0	0
RL2e	0	0	1
RL3e	0	0	0
Rle	0	0	1
LD1e	0	0	5
LD2e	0	0	13
LD3e	11	0	0
Lde	11	0	18
VL1e	0	0	0
VL2e	0	0	0
Vle	0	0	0
LW1e	0	0	0
LW2e	0	6	0
LW3e	0	0	0
Lwe	0	6	0
RL1f	0	0	0
RL2f	0	0	0
RL3f	0	0	0
RLf	0	0	0
LD1f	0	0	1
LD2f	0	0	0
LD3f	0	0	0
LDf	0	0	1
VL1f	0	0	9
VL2f	0	0	0
VL3f	0	0	41
VLf	0	0	50
LW1f	0	0	0
LW2f	0	0	0
LW3f	0	0	0
LWf	0	0	0
C1g	0	0	0
C2g	0	0	0
C3g	0	0	0
Cg	0	0	0
RL1g	0	0	0
RL2g	0	0	0
RL3g	0	0	0
RLg	0	0	0
LD1g	0	0	0
LD2g	0	0	0
LD3g	0	0	0

LDg	0	0	0
VL1g	0	0	0
VL2g	0	0	0
VL3g	0	0	0
VLg	0	0	0
LW1g	0	0	0
LW2g	0	0	0
LW3g	0	0	0
LWg	0	0	0
C2h	0	0	18
C3h	0	0	3
Ch	0	0	21
RL1h	0	0	0
RL3h	0	0	0
RLh	0	0	0
UD1h	0	0	0
UD2h	0	0	0
UD3h	0	0	0
Udh	0	0	0
VL1h	0	0	0
VL2h	0	0	0
VL3h	0	0	0
VLh	0	0	0
LW1h	0	1	0
LW2h	0	0	0
LW3h	0	0	0
LWh	0	1	0