Relating Upriver Dam Creation to the Regeneration of Cottonwoods (*Populus deltoids* Subsp. *monilifera*) within the Upper Missouri River Breaks National Monument

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Abstract:

Many ecosystems within the interior of the North American continent rely heavily on cottonwood species to provide a break from largely homologous and unproductive semi-arid surroundings. This is the case along the National Wild and Scenic Missouri River in north-central Montana. Plains Cottonwoods (Populus deltoides Subsp. *monilifera) within the Upper Missouri River Breaks National Monument are the dominant tree species, found in spaced groves along the river's banks. The cottonwoods support riparian zones that are vital to the success of the entire surrounding ecosystem by providing shade, shelter, food, as well as meeting other needs. However, in recent years it has become clear that the populations of cottonwood trees found in the Monument are aging without a crop of younger cottonwoods to take their place. Cottonwood trees are highly dependent upon riverine conditions to successfully reproduce, and even slight changes in many riverine factors have been found to significantly alter rates of cottonwood regeneration. The Missouri River, like many rivers in semiarid environments, has been dammed for water management purposes and in doing so the natural variability of the river's flow has been altered. Along with altering variable flow rates, such as flooding and other high flow periods, the dams have changed the amount of sediment carried by the river through the monument. Both changes are key aspects of riverine conditions that effect cottonwood reproduction and regeneration. Nine dams exist on the Missouri River above the Monument, as well as one on the Marias River which enters the Missouri River upriver of the Wild and Scenic portion of the Monument. In this research project the age of cottonwoods throughout the Wild and Scenic portion of the Monument was determined by collecting diameter at breast height (DBH) measurements, and comparing them with annual DBH growth from other plains cottonwood groves in similar semi-arid climates. In an attempt to determine which dam, or dams, have had the most impact upon the lack of cottonwood regeneration this study compared the age of the sampled cottonwood trees to the year each dam first impacted the river's conditions. By understanding which dam, or dams, has had the most impact upon the Monument's cottonwoods, future management of flow rates can be adapted to better serve the cottonwoods, and therefore protect the Monument's entire ecosystem and functionality.*

Introduction

Over two centuries ago, in what is now known as the Upper Missouri River Breaks National Monument, Captain Meriwether Lewis remarked at the awe-inspiring natural scenery of the surrounding landscape, "nature presents to the view of the traveler vast ranges of walls of tolerable workmanship, so perfect indeed are those walls that I should have thought that nature had attempted here to rival the human art of masonry had I not recollected that she had first began her work." Today the land is protected in a collection of roughly 375,000 acres in north-central Montana under the supervision of the Bureau of Land Management. The Monument is home to a wide variety of plant and animal life, as well as sites of significant historical and cultural importance.

Within the Monument, the Missouri River meanders 149 miles on its journey from western Montana to its confluence with the Mississippi River at St Louis, Missouri. As it flows through the Monument, the river passes many different natural environments, ranging from remnants of the once vast prairie of the American Great Plains to small patches of deserts. But for the 60 species of mammals, 233 species of birds, and 20 species of amphibians and reptiles that call the Monument home, the riparian zones are the Monument's most important habitat (Graetz).

Riparian zones comprise less than 1% of the total land area (Scott) within the monument, yet they support the majority of animal species, and are home to more bird species than all other habitats combined (Harmata). Plains cottonwoods (*Populus deltoids* Subsp. *monilifera*) are the most vital aspect of the Monument's riparian zones (Braatne). The cottonwoods provide vertical structure to the largely flat and homologous landscape, which thereby creates niches that are not found in any of the other surrounding habitats. Consequently, cottonwoods provide the area with greater species richness and are directly correlated with the overall biodiversity of the entire monument (Auble).

Within the cottonwoods' lower reaches small birds find suitable nesting locations, while the tree canopies provide nesting sites for larger birds, such as eagles and osprey (Rumble, Harmata). Along with providing habitat for birds, the trees provide food and shade for other animal species, such as deer and antelope, during the scorching summer months (Graetz, Beschta). Many plant species take advantage of the shade provided by the large canopies of the cottonwoods as well. Multiple willow and shrub species are closely associated with the cottonwood stands (Taylor, Lesica). Even tree species, such as box elder and green ash, are dependent upon cottonwoods to provide the necessary conditions for their growth and survival (Taylor). Without the plains cottonwood, much of what makes the Breaks a naturally wonderful place would not be possible, and because of this the cottonwood is truly the keystone species within the Monument's total ecosystem (Taylor).

The dependence of the Monument's ecosystems on cottonwoods is similar to the overall dependence cottonwoods have on river conditions for completing their life history. Reproduction is the most intricately related aspect of cottonwood life history with riverine processes (Braatne). Cottonwoods are a dioecious plant species, meaning each tree is either male or female, which is a rare adaption for a North American plant species. Flowering and pollination for the two sexes occurs in early spring prior to leaf initiation (Taylor). During this period rivers are at their highest annual levels from snow melt and spring storm flow (Rood). As spring continues towards summer, fertilized female cottonwoods begin to produce seeds as daily average temperatures reach above freezing levels (Taylor). Each female tree can produce upwards of 25 million seeds annually, with mature seeds weighing only 0.3 to 0.6 milligrams individually (Braatne). Seed dispersal temperature coincides with a return to lower flow rates in rivers, as snowmelt tapers off and heavy precipitation storms begin to decrease. The millions of tiny seeds are covered with cotton-like hairs that allow dispersal by wind or water. After dispersal the seeds are viable for only one to two weeks, although after becoming water saturated the seeds spoil much faster (Braatne). Following deposition on suitable soil, seeds can germinate within 24 hours. Suitable soil for cottonwood germination is moist barren soil (Taylor, Brattne).

Productive cottonwood germination soils are strongly correlated with the decrease in river flow rates. Following the retreat of springtime high flows, the inundated riverbanks and floodplain areas are left devoid of vegetation. Cottonwood seedlings need barren soil due to their small size. The seeds are so small and light due to a lack of an endosperm, which provide the majority of plant seedlings with nutrition in the form of starch. Because of their absence of an endosperm, cottonwood seeds require direct sunlight for at least the first two weeks after germination, and this can only be found on barren unvegetated surfaces (Bhattacharjee). Following germination the seedlings begin photosynthetic processes in less than a day, allowing for rapid growth (Braatne). In the early stages of growth the cottonwoods are highly intolerant of drought, again primarily due to their lack of an endosperm and the need for all nutrients to be available from their environment. Since cottonwood seedlings are so dependent upon water availability, seedling growth is strongly tied to soil type (Bhattacharjee). Sandy and silty soils are better for growth as they tend to retain water longer after the high flows have receded, whereas rocky soils hamper growth due to lower water retention. The soil type of floodplains is reliant upon riverine conditions, as rivers carrying lower levels of sediment are more likely to erode away silt during high flows than deposit more (Whited). While the young cottonwoods are very intolerant of drought they are very tolerant of inundation (Bhattacharjee), which is important for plants living in semi-arid locations that can receive short and intense storm flows throughout the summer months.

Unfortunately, within the Monument, cottonwoods have recently been noted as having a shortage of successful spring reproductive events (Scott, Auble). The majority of cottonwood groves are comprised of trees nearing the end of their 100 to 150 year lifespan (Auble, Braatne). Previous studies of cottonwoods have identified a strong correlation between the construction of upriver dams and a change in the reproductive ability of downriver cottonwoods. Principally, this is due to the fact that dams control and alter the two primary factors that determine size, shape and overall morphology of rivers and floodplains, with those factors being flow rates and sediment load (Burke). The prevalence of dams worldwide has made floodplain riparian zones among the planet's most threatened ecosystems (Whited). And therefore dam construction has also greatly impacted populations of floodplain dependent species, such as cottonwoods.

After a dam is constructed the downstream flow beyond the dam is dictated by the dam's management plan. For many dams this means moderating spring time flows to lessen the economic impacts of downstream flooding, so to do so the increased spring flow rates are held within the dam's reservoir for later months (Burke). Along with the intentional holding of water, dams also cause the unintended loss of sediment within river systems (Whited). As a river nears a dam its velocity begins to slow causing the river's sediment load begins to drop out of suspension and deposit upriver from the dam. For points downriver from dams the outcome of upriver dam creation is almost always reduced annual flow rates and lower levels of sediment (Burke). For cottonwoods both of these primary outcomes are devastating, as millenniums of evolving with natural river processes have left the trees unable to adjust to new conditions. This leaves downriver cottonwoods outcompeted and without sustainable populations (Rumble).

The relatively constant flow rates below dams have consequences for cottonwoods beyond lack of moist and barren soils. Natural high flow events allow cottonwoods to establish themselves at a variety of elevations above the low winter flows (Hall). In many of the semi-arid environments that make up the cottonwoods' native range this is important during the long cold winters. During the winter months, frequent ice flows are carried down river. Along their path the ice flows scour the riverbanks at an elevation multiple feet above the flow level (Rumble). During the scouring events, all vegetation in the ice's path is removed from the banks due to sheer weight and friction force. Unfortunately for cottonwoods the ice scours are not selective and remove young cottonwoods along with the other vegetation. Therefore, cottonwoods require high enough springtime flows to produce barren soil for seedling germination above the level of which ice scours will reach in subsequent winters (Hall). But on dammed rivers the problem arises as constant flow rates not only don't produce much barren soil, but any seedlings in the late spring and summer are not high enough to avoid the winter's ice scourings.

Above the monument, there are nine dams along the Missouri River, beginning near the river's source in the Rocky Mountains and being closest to the Monument just outside of Great Falls, Montana (Auble). Flow rate of the Missouri River within the Monument is also affected by tributaries entering the Missouri prior to its course through the Monument. These tributaries are the Smith, Sun, Teton, and Marias rivers. The largest of these is the Marias River (Rood), whose confluence with the Missouri River is within the Monument's borders. The Marias River is dammed by a large earth fill dam, known as Tiber dam.

Dam	Year of Construction
Missouri River	
Toston	1940
Canyon Ferry	1949
Hauser	1912
Holter	1918
Black Eagle	1927
Rainbow	1910
Cochrane	1958
Ryan	1915
Morony	1930
Tributaries	
Tiber (Marias)	1952
Gibson (Sun)	1926

Table 1: The upriver dams on the Missouri River and tributaries (from top in order of geographic location from the river's source), with year of construction

Within the Monument the Missouri River's flow rates are most impacted by the upriver Canyon Ferry Dam and Tiber Dam on the Marias River tributary (Auble). Canyon Ferry Dam is located approximately 20 miles to the east of Helena, Montana, and is a gravity dam positioned in the river valley between the Big Belt Mountains and the Spokane Hills. Construction of the dam began in 1949 and was completed in 1954 (Bureau of Reclamation (a)). Behind the dam is Canyon Ferry Lake, a reservoir with up to a 1,997,900 acre·ft capacity, making the reservoir the third largest body of water in Montana (Bureau of Reclamation (a)). The reservoir has been used to produce electricity, irrigation, and control downriver flooding since its construction. Tiber Dam is one of the largest earth fill dams in the world, and is located in Chester, Montana. The reservoir behind the dam is known as Lake Elwell. The reservoir has a total capacity of 1,515,000 acre·ft (Bureau of Reclamation (b)). Construction of Tiber Dam started in 1952 and was completed in 1956 (Bureau of Reclamation (b)). As these are the two major dams influencing the flow rates within Breaks, it can be understood that the majority of change to the river system has taken place since around 1954.

Previous research has determined that successful germination and regeneration of cottonwoods within the Monument is tied to flow rates of over 1400 m^3/s in Fort Benton (Bovee), a town on the Missouri River just upriver from the Monument's western boundary. Within the Monument, this corresponds with flows of over 1850 m^3/s (Bovee) as the Marias River meets the Missouri downriver from Fort Benton and significantly increases the Missouri's size. But since 1954, the year that Canyon Ferry Dam was created, the magnitude of flows over this size as well as the overall frequency of flows at this rate has decreased by as much as 40 to 50 percent (Bovee).

Due to the dependency of cottonwoods on high flow rates it's clear that reduction in occurrence and magnitude of flows have had at least some impact on the lack of cottonwood regeneration. The purpose of this research was to help establish approximate current ages for trees found within the Monument's cottonwood groves, and compare the collected ages with the dates of upriver dam creation. An association between the age of trees within the Monument's groves and dam construction date would signal a correlation between the dam creation and the end of successful cottonwood reproduction and regeneration within the Monument.

Study Area

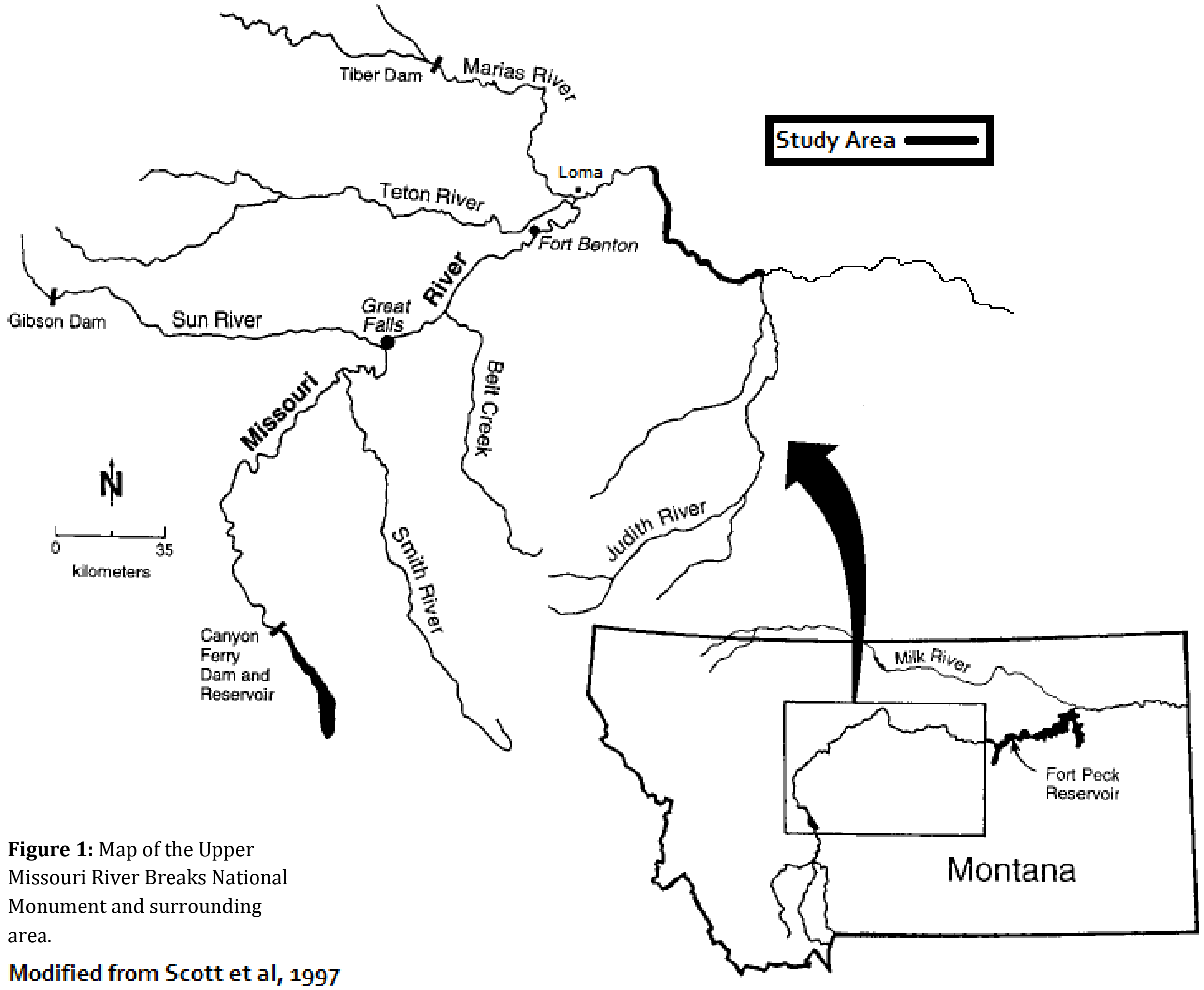

Figure 1: Map of the Upper Missouri River Breaks National Monument and surrounding area.

Modified from Scott et al, 1997

The Upper Missouri River Breaks National Monument is located in what is classified as a cold continental semi-arid climate (Köppen Climate Classification: BSk) (Graetz), characterized by long cold winters and short hot summers. At latitude of approximately 47°

47’ N (Krause C) the Breaks lie within the westerly wind belt, which brings air masses to the region from off of the Pacific Ocean. As the air masses bringing weather travel inland and over mountain belts they lose moisture, leaving the Breaks with low annual precipitation rates of around 31.623cm (National Weather Service). Sitting over 1450 kilometers inland from the Pacific Ocean the temperature in the monument is dictated by the amount of radiation emitted by the land over which the air masses travel. In the winter, air masses with mild temperatures must pass over the colder land as they are blown inland, lowering temperatures and giving the Monument its dry cold winters. During the summer the opposite is true, as air masses with mild temperatures pass over warmer land, raising the temperature. This results in the hot summers summer months, which also bring the majority of precipitation. Over a third of the limited precipitation falls during short intense storms in the months of May and June (Scott). Extreme weather conditions on a daily scale are common in the region. And the largest 24-hour temperature change in the continental United States occurred just north of the Monument’s boundary in Loma, Montana, a change from -47.7°C to 9.4°C (Weather Underground.).

In the Breaks, topography can change just as quickly as the temperature. This can be attributed to the Monument’s geology. Ninety million years ago beaches covered what is now the Monument, as the Western Inland Seaway extended over a large swath of North America for approximately 30 million years (Monahan). Central Montana was along the edge of the seaway and changed from being covered in beaches to being hundreds of feet below water in correspondence with the seaway’s fluctuations. During the time of its existence the seaway deposited sediments across its range, sand along its beaches, along with silt and clay in deeper waters. As the water level fluctuated the sediments became exposed and solidified into rock layers. These layers, now forming sandstone, siltstone, and shale, can be seen throughout the Breaks on the slopes leading down to the river (Monahan).The next large geologic event to shape central Montana was a period of volcanism around 55 million years ago (Monahan). Often volcanism is thought of as eruptions and volcanos, but the volcanism within the region during this time period was rarely seen above the ground surface. Instead the igneous rocks now seen throughout the Breaks as spires and outcroppings originally cooled underground as basaltic igneous intrusions. Over time the sedimentary rocks above them have eroded away and left the stronger volcanic formations exposed. The principal geologic event to shape the Monument’s current appearance was the last great period of glaciation beginning two million years ago (Monahan). Prior to glaciation the Missouri River flowed northeast into Hudson Bay, but as the earth cooled and glaciers began to extend equatorially the river’s northern path was cut off. The dammed river began to pool up and form glacial lakes, until eventually water levels rose within the lakes and the overflow began to run off along the glacier’s southern front. Over time this run off began to incise itself into the weak sedimentary rocks, forming a river channel. Following the period of glaciation the Missouri River established itself along its new channel bed following the glacier’s southern front, which is where it remains today. Today the Missouri has further incised into the area’s sedimentary rocks, and river valley with a 150 to 560 meter elevation change from the valley’s rim to the riverbed (Scott).

Such a great elevation change has produced the wide array of environments found in the Monument. Above the valley’s rim, prairies are the predominate ecosystem, (Kudray, G, Johnson W) supporting many species of grasses and sage brush. The slopes leading down to the valley's floor differ in their environmental structure depending on their aspect. South-facing slopes are drier due to more direct solar radiation, and therefore support little vegetation, whereas the north-facing slopes have moister, deeper soils and can support trees and shrubs. Close to the river the soil is richer, due to deposition of alluvial sediments, along with greater water saturation. As the distance from the river increases so does the lack of soil nutrients and an overall drying of the soil. Along the river, riparian forests of cottonwood, green ash, and box elder are found. Further from the riverbed short grasses dominate, as well as cacti in small desert microclimates (Johnson).

Animals within the Monument are generally associated with specific environments and plant types. In the upland prairies, western wheat grass and downy brome support prairie dogs and other rodents (Graetz). The south-facing slopes are home to many of the reptile species, due to its direct sunlight, while the north-facing slopes support small ponderosa pines, Douglas firs, and junipers, along with much of the larger mammal species (Krause). Large mammals in the monument include mule deer, pronghorn antelope, mountain lion, and even the occasional wolf or grizzly bear. On the valley floor black greasewood and sage brush species provide homes for reptiles and smaller mammals (Monahan). In the riparian zones cottonwoods, green ash, and box elder trees (Rumble) provide nesting locations for many of the bird species, including osprey and golden eagles (Harmata). Birds make up the majority of the animal species found in the Breaks, with up to 230 species residing in the Monument.

Methods and Materials

Field data collection occurred during a six day period from August 25, 2012 to August 31, 2012. Thirty four cottonwoods were sampled for height estimations and diameter at breast height readings and another eight trees were cored to produce age samples. The trees that were sampled for height and diameter at breast height were located within five groves in the "Wild and Scenic" portion of the Monument, between river mile 52 and river mile 84.5 of the Monument.

To collect readings of diameter at breast height (DBH) for trees in the monument two vinyl tape measures were used. One vinyl tape was used to determine the proper breast height measurement, at 4 feet 6 inches above the ground, and the other to record the tree's circumference. At each recording two researchers were present to ensure that the circumference measuring vinyl tape was level with the ground, as to not produce a false reading of tree circumference. After recording the circumference for each tree, the reading was equated into diameter using the equation: $d=\pi/C$, in which d is diameter and C is circumference.

Following the collection of the DBH reading, the height of each tree was measured. To do so the researcher stood at a known distance from the base of the tree and measured the angle between his position and the top of the tree using a clinometer. From the known distance of sampling and the known angle the height was determined using the equation: $h=d(\tan(a))+t$, for which h is the height, d is the distance from the tree's base that the reading was taken, a is the recorded angle, and t is the height off the ground that the clinometer was held.

Following the completion of data collection and field work, the DBH readings and height estimations were analyzed to determine if an association between the two was present. To do so the two data sets were tested for a correlation using the Pearson product-moment correlation coefficient. This testing determined the linear association between the height estimations and the DBH, an association that would be helpful in future testing of cottonwoods for age and growth rates.

Along with testing for a correlation between height and DBH, the most important work was assigning each sampled tree an estimation of age. To do so data compiled from a previous study was used. The study was conducted by Keith Wood, of the Colorado State Forest Service, in which he sampled the change in DBH over a 16 year period for multiple tree species in Westminster, Colorado (Wood). In total 271 plains cottonwoods were monitored annually for change in DBH between the years of 1992 and 2008. From the study a growth rate of 0.64" DBH annually was established. Unfortunately, the climatic conditions for trees in Westminster and the Monument are much different. Because of this the established annual DBH growth could not be directly substituted between the two locations. Therefore in an attempt to compensate for the difference in climate, the different precipitation levels and average frost free period were compared. In Westminster the annual precipitation level is 14.36" (National Weather Service (a)), whereas in the Monument the annual level is 12.45" (National Weather Service (b)). Resulting in a relationship between the two of 0.86, this ratio was then applied to growth rate produced by Wood and gave an annual growth rate of 0.55". Along with precipitation differences, the average temperature in the Monument is seven degrees colder than Westminster and therefore the frost free periods are different. Frost free periods are important for plant species as they correspond to the length of the growing season, and therefore impact the amount of annual growth. To adjust for growing season length the ratio between average frost free days as also calculated, using growing seasons of 157 days in Westminster (National Weather Service (a)) and 124 in Great Falls, Montana (National Weather Service (b)), which is the nearest city to the monument for which average frost free days are calculated. The resulting ratio was 0.79. After assessing this ratio to the altered growth rate of 55" the annual growth rate became 0.43", which ends up giving the Monument's cottonwoods an annual growth rate approximately two thirds the annual growing rate in Westminster.

It must be noted that the process in which the ratio between the annual DBH growth rates for cottonwoods in Westminster and the Monument was calculated may be flawed. However, without a standardized method in which to compare different regions for their growth rates this is certainly as good a way as any. Precipitation and frost free days are influential in the amount of growth a plant has annually, so by comparing these aspects of the different climates a significantly important ratio can be calculated.

This final annual growth rate for DBH was applied to the trees, by dividing the recorded DBH for each tree by the modified growth rate, and resulted in our final age estimates. After determining the age of the trees the next step was to calculate the necessary statistical metrics within the population sample. Necessary metrics were the minimum, median and mean ages, as well as standard deviation from the average. By calculating these values the ages then began to show significance in regards to dates that dam were built in the Missouri River Watershed upriver from the Monument. From calculating the median and mean ages it became clear what the typical age of cottonwoods within the riparian groves was. With this data the standard deviation then allowed for identification of the period in which meaningful successful reproduction ended, because trees older than and within one standard deviation of the mean could be argued as being significantly important to the study. Trees outside of these parameters would be considered outliers, and therefore statistically insignificant.

Results

Tree Coring

Originally one of the main objectives of this research was to establish a formula for estimating the age of the Monument's cottonwoods, as well as other cottonwoods in similar climates, by comparing the height, diameter at breast height (DBH), and age. The plan was to determine age by tree ring core samples. A possible correlation could have been turned into a formula, such as A=(D+H)C, with A being age, D being DBH, H being height, and C being any needed coefficient. Unfortunately, while in the field the tree coring turned out to be as tricky as previous cottonwood researchers have found in their studies (Scott, Auble). Examples of the difficulty include being off by as much as 15 years in aging from above ground cores (Scott), multiple or no rings for individual years, and not being able to extract whole core samples. With the tree borer used for our core samples the cores themselves would not remain intact. As soon as the sample was removed from the borer the core broke into segments, ranging from millimeters to several centimeters in size. Due to this no accurate age data was collected for individual trees, and no connection between DBH, height, and age could be calculated.

Height-DBH Correlation

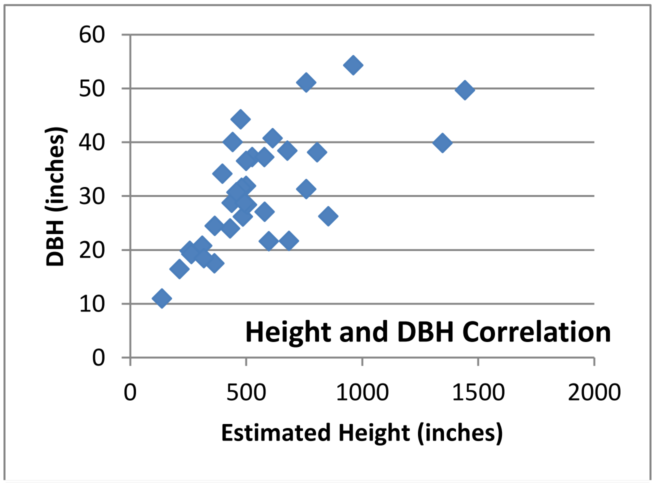

Figure 2: A graphical representation of the height and diameter at breast height for each sampled tree

Height and diameter at breast height (DBH) values of the selected cottonwoods showed a slight association. Between the two metrics a correlation coefficient value of 0.674374 was calculated. Meaning that between the two sample sets a relationship existed but not of much statistical significance. Therefore, at least for the sampled cottonwoods in the Monument, it was determined that height and DBH values are connected, but not to a point in which knowing one has the ability to help calculate the other reliably. It is interesting that for the data collected the smaller trees showed a greater correlation, which could be important for further research into the growth rates of cottonwoods. This association can be seen in figure two, prior to the DBH values of 40 inches and greater. One possible explanation for this association at younger ages could be due to the growth of cottonwoods, in which growth rates are much more controlled by genetics rather than environment at younger ages.

Tree	Height (Inches)	DBH (Inches)	Age (Years)
1	685.98	21.65	49.78
2	438.51	28.73	66.07
3	257.71	19.81	45.57
4	137.66	10.98	25.26
5	614.49	40.74	93.71
6	580.15	27.06	62.23
7	311.02	20.79	47.81
8	264.92	19.26	44.29
9	486.28	26.17	60.18
10	598.14	21.58	49.64
11	214.12	16.46	37.85
12	855.11	26.23	60.32
13	505.16	28.39	65.30
14	492.92	28.74	66.11
15	500.22	31.89	73.35
16	432.17	24.00	55.20
17	365.38	24.48	56.30
18	481.41	31.51	72.48
19	459.31	30.72	70.65
20	1347.39	39.87	91.69
21	1443.35	49.66	114.21
22	760.24	51.09	117.50
23	477.21	44.25	101.76
24	526.49	37.24	85.65
25	397.96	34.14	78.52
26	500.22	36.53	84.01
27	442.35	40.03	92.06
28	760.24	31.27	71.93
29	579.35	37.24	85.65
30	678.53	38.44	88.40
31	807.26	38.12	87.67
32	364.44	17.51	40.26
33	318.19	18.46	42.46
34	962.88	54.27	124.82

Table 2: Entire data set for height estimations, diameter at breast height, and age calculations.

Diameter at Breast Height and Age

Using the previously described diameter at breast height (DBH) growth rate of 0.43 inches per year, age was determined for each sampled cottonwood by simply dividing the collected DBH by the annual growth rate. The resulting number was the estimated age. Ages for the sampled cottonwoods ranged from just over 25 years old to nearly 125. Overall the mean of the sample was 70.84 years old, with a standard deviation of 23.71. Meaning the majority of the sampled trees were between the ages of 47 and 93, which was calculated using one standard deviation value above and below the mean. This was consistent with other studies that showed the majority of cottonwoods were in the later stages of their lifespan, with that being 100 to 150 years (Lytle, Johnson). Obtaining this information was important because it clearly points to a lack of younger trees, and therefore a problem with grove regeneration.

Age and Dam Creation

Following the calculation of the statistical metrics of the age values for the sampled Cottonwoods the most important aspect of the research was done by determining the most recent period of years in which reproduction and regeneration was successful. This year, or years, would indicate when changes to the environment began to impact cottonwood reproduction and regeneration. To do so the sum of one standard deviation from the mean and the mean was subtracted from the year of the study (2012). From which the year 1964 as determined, this symbolized the most recent year in which significant reproduction and regeneration could have occurred. Along with this the average age was subtracted from the year of data collection to give the furthest edge of the period in the last successful regeneration could have occurred, which resulted in the year of 1941. From this the median within the range, 1953, was assessed as being the year in which regeneration and reproduction was last at a successful rate, due to the middle of the range being the most certain year of impact.

Age Values	
Minimum	25.25
Median	68.37
Mean	70.84
Standard Deviation	23.71
Average Year of Impact	1952-53
Range of Impact	1941-1964

Table 3: Selected data values important to the data sampling of the cottonwood ages.

The year 1953 is significant because it was the last year prior to the completion of Canyon Ferry Dam, and was three years prior to Tiber Dam's completion. A relationship between the last year of successful reproduction and the year prior to major upriver dam completion is not surprising at all given that cottonwoods rely so heavily on riverine conditions. It is surprising how significantly the two dams are implicated by the calculated year of last successful cottonwood reproduction and regeneration. This association also is very much in line with previous studies that have identified Canyon Ferry and Tiber Dams as the most impactful regulators of flow rates in the Monument (Bovee).

Discussion

From the data it is clear that a correlation exists between the first years of operation for both Canyon Ferry and Tiber Dams and the regeneration of cottonwood groves within the Monument. The question then becomes what changes can be implemented to help lessen the impacts the dams have on the cottonwoods, and therefore the Monument's entire ecosystem. The most possible solution to the problem would simply be from a hydrologic standpoint. As was previously mentioned the minimum needed flow rate to produce successful deposition and germination of cottonwood seeds within the monument is 1850 m^3/sec (Bovee), therefore flow management could be altered for flows at this point every spring. Possibly even increasing the flow beyond this point, if it was determined that higher flows would produce greater amounts of barren soils and higher sediment deposition rates. Unfortunately, as is the case with many dam and environment standoffs, the solution is not so cut and dry.

Indicated Dams		
Name	**Construction**	**Reservoir Size**
Canyon Ferry	1949	1,997,900 acre·ft
Tiber	1952	1,515,00 acre·ft

Table 4: These are the dams which fit within the period for which the Monument's cottonwoods last successfully reproduced.

Allowing higher flow rates from dams in early spring would mean an increase in flooding damages downriver. And because of this releasing higher flow rates from Canyon Ferry Dam is highly unlikely, as the long reach of the Missouri River between the Monument and the dam contains many commercial, industrial, agricultural, and even residential zones. But between Tiber Dam and the Monument very little exists, and the overall distance is much shorter. Therefore the economic losses from flood damage caused by increased spring flows from Tiber Dam would be minimal. Another problem with releasing higher amounts of water in spring is the loss of electricity and irrigation during the later summer months. Tiber Dam would be hit hard in both aspects of losing high spring waters, due to large irrigation requirements in the semi-arid agricultural lands surroundings the dam. However, the geographic location of Tiber Dam could be used to remedy this problem.

Directly beyond the Monument the Missouri River flows through the Charles M. Russell National Wildlife Refuge, and into Fort Peck Lake. Fort Peck Lake is a reservoir that was formed after the construction of Fort Peck Dam. The reservoir is the fifth largest reservoir in the country and the second largest water body in Montana. With its immense size the reservoir has the capability of receiving higher flow rates during spring without having a large change to its water level. Also the water lost from Lake Elwell, behind Tiber Dam, would not be lost and could still be used to produce electricity or irrigation from within Fort Peck Lake. Due to the relative closeness of the two areas this would be an economically viable option, while helping to return the natural flow regime back to the Missouri River in the Monument.

Changing the management plan of flow rates from Tiber Dam is certainly far from something that can be done overnight, and any changes would undoubtedly run into many opponents. But it is clear that such a change is both possible and necessary for the Upper Missouri River Breaks National Monument to remain a functional ecosystem. Failure to act quickly and accordingly leaves the Monument's ecosystem in serious danger of total ecological collapse. Total collapse is nearly impossible to compute into monetary value. The fact that even after America's westward expansion this area remained largely untouched by human induced changes makes the Monument a highly valuable resource environmentally, culturally, and even economically. Too many of America's great natural landscapes and resources have been lost in the name of economic advancement, but it is not too late for the the Upper Missouri River Breaks National Monument to be saved. The simple adaption needed within the area's water management strategy is something that can produce almost immediate results, and will save this important piece of American history and ecology.

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Literature Cited

Auble G, Scott M, Frazier J, Krause C, Merigliano M. Cottonwood in the Missouri Breaks National Monument. Collaboration of United States Geological Survey, Bureau of Land Management and the University of Montana.

Beschta R. Reduced Cottonwood Recruitment following Expiration of Wolves in Yellowstone's northern range. *Ecology* [serial online]. February 2005;86(2):391-403. Available from: Academic Search Premier, Ipswich, MA. Accessed May 28, 2012.

Bhattacharjee J, Taylor J, Smith L, Spence L. The Importance of Soil Characteristics in Determining Survival of First-Year Cottonwood Seedlings in Altered Riparian Habitats. *Restoration Ecology* [serial online]. December 2008;16(4):563-571. Available from: Academic Search Premier, Ipswich, MA.

Bovee K.D., and M.L. Scott. 2001. Effects of flow regulation on the upper Missouri River: Implications for flood pulse restoration. *Regulated Rivers: Research and Management.*

Braatne JH, Rood SB, and Heilman PE. 1996. Life history, ecology and conservation of riparian cottonwoods in North America. In: Stettler RF, Bradshaw HD, Heilman PE, and Hinckley TM (Eds). Biology of *Populus* and its implication for management and conservation.Ottawa, ON: NRC Press.
Bureau of Reclamation (a). Canyon Ferry Dam –United States Department of the Interior. From http://www.usbr.gov/projects/Facility.jsp?fac_Name=Canyon+Ferry+Dam

Bureau of Reclamation (b). Tiber Dam –United States Department of the Interior. From http://www.usbr.gov/projects/Facility.jsp?fac_Name=Tiber+Dam

Burke M, Jorde K, Buffington J. Application of a hierarchical framework for assessing environmental impacts of dam operation: Changes in streamflow, bed mobility and recruitment of riparian trees in a western North American river. *Journal Of Environmental Management* [serial online]. July 2, 2009;90:S224-S236. Available from: Academic Search Premier, Ipswich, MA.

Graetz R and Graetz S. Montana's Upper Missouri River Breaks National Monument. Northern Rockies Publishing. 2001.

Hall J, Pollock M, Hoh S. Methods for Successful Establishment of Cottonwood and Willow Along an Incised Stream in Semiarid Eastern Oregon, USA. *Ecological Restoration* [serial online]. September 2011;29(3):261-269. Available from: Academic Search Premier, Ipswich, MA. Accessed May 28, 2012.

Harmata P, Restani M, and Hatmata A. 2007. Settlement patterns, foraging behavior, and reproductive success of ospreys along a heterogeneous riverine corridor. Canadian Journal of Zoology

Johnson W, Dixon M, Werner B, et al. Forty Years of Vegetation Change on the Missouri River Floodplain. *Bioscience* [serial online]. February 2012;62(2):123-135. Available from: Academic Search Premier, Ipswich, MA.

Krause C, Forsyth M, Peters J, Fulbright J, Schaefer M, Jacobs C, Keever K, Plovanic G, Tucek D, and Slagel G. *Upper Missouri River Breaks National Monument-Managers Report* . Colaberation of United States Geological Survey, Bureau of Land Management.

Kudray, G, Hendricks P, Crowe E and Cooper S. 2004. Riparian Forests of the Wild and Scenic Missouri River: Ecology and Management. Report to the Lewistown Field Office, Bureau of Land Management. Montana Natural Heritage Program, Helena, MT

Lesica P, Miles S. Ecological strategies for managing tamarisk on the C.M. Russell National Wildlife Refuge, Montana, USA. *Biological Conservation* [serial online]. October 15, 2004;119(4):535-543. Available from: Academic Search Premier, Ipswich, MA.

Lytle D, Merritt D. Hydolocial Regimes and Riparian Forests: A Structured Population Model of Cottonwood. *Ecology* [serial online]. September 2004;85(9):2493-2503. Available from: Academic Search Premier, Ipswich, MA.

Monahan G, and Biggs C. Montana's Wild and Scenic Upper Missouri River. Northern Rocky Mountain Books. 2001.

National Weather Service (a). *Average Weather for Westminster, CO - Temperature and Precipitation*. From http://www.weather.com/weather/wxclimatology/monthly/graph/USCO0403

National Weather Service (b). *Average Weather for Loma, MT - Temperature and Precipitation*. Retrieved from http://www.weather.com/weather/wxclimatology/monthly/graph/USMT0210

Nielsen J, Rood S, Pearce D, Letts M, Jiskoot H. Streamside trees: responses of male, female and hybrid cottonwoods to flooding. *Tree Physiology* [serial online]. December 2010;30(12):1479-1488. Available from: Academic Search Premier, Ipswich, MA.

PPL. Pennsylvania Power and Light Montana. Retrieved on May 26, 2012, from http://www.pplmontana.com/producing+power/power+plants/PPL+Montana+Hydro.htm

Rood S, Goater L, Mahoney J, Pearce C, Smith D. Floods, fire, and ice: disturbance ecology of riparian cottonwoods. *Canadian Journal Of Botany* [serial online]. November 2007;85(11):1019-1032. Available from: Academic Search Premier, Ipswich, MA.

Rood, Stewart B., and John M. Mahoney. "River damming and riparian cottonwoods along the Marias River, Montana." *Rivers* 5.3 (1995): 195-207

Rood SB, Braatne JH, and Hughes FMR. 2003a. Ecophysiology of riparian cottonwoods: streamflow dependency, water relations and restoration. Tree Physiol 23: 1113–24.

Rumble M, Gobeille J. Avian Use of Successional Cottonwood (Populus deltoides) Woodlands Along the Middle Missouri River. *American Midland Naturalist* [serial online]. July 2004;152(1):165-177. Available from: Academic Search Premier, Ipswich, MA.

Scott M, Auble G, and Friedman J. Flood Dependency of Cottonwood establishment along the Missouri River, Montana, USA. United States Geological Survey, 4512 McMurry Avenue, Fort Collins, Colorado 80525-3400 USA

Scott, M.L., and G.T. Auble. 2002. Conservation and restoration of semi-arid riparian forests: a case study from the upper Missouri River, Montana, USA. Flood Pulsing and Wetland Restoration in North America

Scott M, Skagen S and Merigliano M. 2003. Relating Geomorphic Changes and Grazing to Avian Communities in Riparian Forests. Conservation Biology

Taylor J 2001. Populus deltoides. In: Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). Available: http://www.fs.fed.us/database/feis/

Weather Underground. Wunderground Annual Average Temperatures, Fort Benton Montana. Retreived on June 5, 2012, from http://www.wunderground.com/NORMS/DisplayNORMS.asp?AirportCode =KGT F&SafeCityName=Fort_Benton&StateCode=MT&Units=none&IATA=GTF&MR=1

Whited D, Lorang M, Harner M, Hauer F, Kimball J, Stanford J. Climate, Hydrological Disturbance, and Succession:Drivers of Floodplain Pattern. *Ecology* [serial online]. April 2007;88(4):940-953. Available from: Academic Search Premier, Ipswich, MA.

Wood, K. (January 2010). Growth Rates of Common Tree Species in Westminster, Colorado. *Colorado State Forest Service*. doi: www.csfs.colostate.edu