continual process for beavers, and this spiral of II.
creation, maintenance, abandonment, reutilization, III.
maintenance is on-going throughout the beavers' habitat. We are investigating this premise and comparing the dynamics of the process in beaver ponds and river channels.

This project will focus on modeling climate change impacts on the terrestrial and aquatic habitat of beaver utilizing ponds and rivers. The research project has five main objectives:

1. Complete an ongoing census of beaver colonies in Grand Teton NP represented by Gribb (2011).
2. Determine the general habitat characteristics of beaver along the Snake River and the pond areas of GTNP.
3. Using the different climate change models create a scenario of temperature and precipitation changes in the Greater Yellowstone Ecosystem.
4. Utilizing the results of the models, examine the predicted climate change impacts to water resources in GTNP.
5. Analyze the beaver distribution based on the water resources impacted by the climate change models.

While ponds are fed from sub-surface water and tributaries, the lower Snake River is subject to controlled flow from the Jackson Lake reservoir. The results of this study will have management implications for GTNP when working with the Bureau of Reclamation to determine the seasonal water storage and release patterns into the Snake River. Recommendations for protection of ponds and translocation of beavers can be made depending upon the outcome of the climate modeling.

✦ SIGNIFICANCE

This research is focused on the potential changes to the Snake River ecosystem based on a climate change model. An immediate impact to the ecosystem will be to those species that have habitat directly associated with the Snake River. The beavers in this area have had dramatic population changes in the last 40 years and with the model predictions there could be further changes to the river ecosystem. Policy strategies will be examined in response to the changing ecosystem and this will provide the GTNP with some options for wildlife management. A peer-reviewed research paper in River Research and Applications is anticipated. Further, research proposals to the Wyoming Water Development Commission, NSF and the Columbia River Basin Commission are forth-coming.

✦ METHODS

This project will employ three research methods: an inventory and compilation of beaver habitat characteristics, field and aerial surveys of beaver lodge and den locations, and modeling of streamflow using climate change models. The first two methods are interrelated. Historic data on beaver locations will provide areas of past environmental conditions relating to vegetation and soils. This information will be incorporated into a more robust model of beaver habitat. Current beaver locations will be collected by field and aerial surveys. Vegetation and soil characteristics will be compiled from existing GIS-formatted spatial data to provide base data for the beaver habitat model. The aerial beaver census will provide base information on colony locations in a wider range of areas not covered by the ground field survey. The NOAA regional climate data center will provide historic data on temperature and precipitation for Region 2, the Central Rockies including Grand Teton National Park.

Beaver habitat characteristics were compiled from three different sources. First, the historic records of Collins (1977) and Gribb (2011) that provide vegetation and soils information at historic beaver lodges and bank dens. Second, current vegetation and soils data were collected and compiled from existing data sets from the US National Park Service, US National Resources Conservation Service, US Forest Service and the Wyoming Geographic Information Science Center (WyGISC). Finally, by utilizing high resolution WorldView2 satellite imagery from DigitalGlobe, an updated vegetation classification can be completed for areas inhabited by beavers as identified from the field and aerial survey.

Several different climate change modelling schemes have been developed to determine climatic conditions into the future. The US Forest Service in conjunction with ESSA have generated a model of general climate change that can be utilized for the central Rocky Mountain region, FVS. The model has the flexibility to incorporate several scenarios of change in temperature and precipitation. Thus, the model using the Global Circulation Model (GCM) with Regional Climate Models (RCM) developed by NOAA's GeoPhysical Fluid Dynamics Laboratory (NOAA-GFDL_CM2.1) at a higher spatial resolution will be incorporated following the 21st Century A1B scenario (IPCC,2007). The USDA's Soil and Watershed Assessment Tool (SWAT) will also be examined to determine if it can assist in analyzing the meteorological inputs at a watershed level. The combination of these models will allow this research to utilize model changes at a higher spatial resolution. For example, Jha and Gassman (2014) were able to model change at the sub-basin (HUC 12) unit level, creating hydrological response units (HRU).

Input into the SWAT model requires data on topography, soils, precipitation, temperature, solar radiation, wind speed, relative humidity and land use/land cover. The nine weather stations surrounding the study area will provide the climate and weather information required for this study along with the GCM-RM models. Land use will be classified using WorldView2 high resolution satellite data from DigitalSpace Imagery. Land use/land cover will be classified relative to beaver habitat parameters (Allen 1983, Gribb 2011). As examples relevant to our project, climate change models have predicted decreases in cottonwoods (*Populus spp.*) and willows (*Salix spp.*) in the Rocky Mountain region (Scott et al., 2013, Wood et al., 2013, and Kaczynski and Cooper 2013), major vegetation factors in beaver habitat. McWethy et al. (2010) provides a long term perspective on western U.S. climate change and their conclusions of incorporating the multi-millennial climate drivers into climate change models will be a fundamental concept in this study.

Modeling river discharge will follow the work of St. Jacuqes et al. (2013) and Dettinger et al. (2004) to estimate streamflow and its characteristics for river beaver habitat. Both studies use a generalized least squares regression model to determine flow rates for the mid-century scenario.

✦ PREVIOUS WORK

The Co-PIs have conducted field surveys for beavers in GTNP since 2002. The work of Collins (1974-1977) identified 65 colonies along the Snake River and 112 throughout Grand Teton NP. Gribb and Harlow have conducted aerial surveys in 2006 and 2010 and have identified and mapped the decreasing beaver colonies in GTNP (Figure 1).

✦ ANALYSIS

The first stage of this project had two parts, to field inventory beaver lodges and conduct an aerial census of beaver colonies. The field inventory of beaver lodges and bank dens was conducted through June and August, 2014. A total of 83 active lodges and dens were located across Grand Teton NP. These lodges and bank dens displayed activity by having recently browsed willow stems either at the lodge/den entrance or in close proximity or they were displayed

Nelson Reach-BI	Collins (1977)	Aerial Census (2006)	Aerial Census (2010)
2-1	2		1
1-2	3		
0-1	1	1	1
3-1	4		1
4-1			1
5-2	2		
6-2	1	1	1
7-3	8	7	2
8-1		2	
9-2	7		2
10-1	8		
11-1	2		
12-2	3	1	1
13-1	1	13	
4-2	16	2	3
15-1	3		
16-3	4		3
17-3			2
18-1			
19-2			
Totals	65	27	18

Figure 1. Beaver locations along the lower Snake River reaches.

on the top or side of the lodge. The second part of the inventory was an aerial census survey of beaver caches following the Snake River, Gros Ventre River, Cottonwood Creek, Buffalo Fork, Pacific Creek, and the upper Snake River above Jackson Lake Dam and the major tributaries going into Jackson Lake.

The aerial survey was conducted on November 3, 2014 and took approximately six hour to complete. Figure 2 illustrates the distribution of the caches that were located. A total of 76 caches were found throughout the park. Overall, 22 of the caches (28.9%) were pond or lake caches and the remaining 54 (71.1%) were along the major rivers or their back channels. The difference between the field observed lodge/bank dens and the aerial survey is that the field-

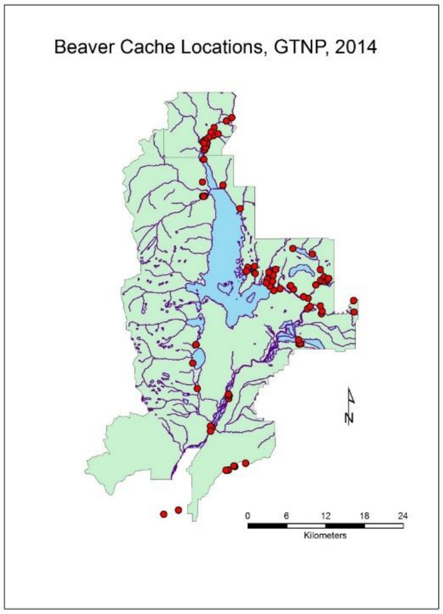

Figure 2. Beaver cache locations, aerial survey 2014.

observed lodges and bank dens represent areas that beavers utilized throughout the summer, but may not be lodges/dens that were used in the winter so they did not cache. Whereas, the caches represent lodges/bank dens that would be used during the winter because the beavers cached food that they could easily access from the lodge/bank den entrance.

The digital vegetation data came from the Grand Teton NP GIS Center and was part of a 2005 study of vegetation throughout the park extracted from USGS NHP imagery (2002). Overall, a total of 51 vegetation classes were identified in the park, of which seven categories were identified as potential vegetation communities associated with beaver habitat: willow shrubland, alder shrubland, mixed conifer-cottonwood riparian forest, mixed evergreen-popular forest, cottonwood riparian forest, aspen forest, and artic willow dwarf shrublands.

Nicholas (2007) divided the lower Snake River (Jackson Lake Dam to Moose, WY) into 20 reaches. The reaches were classified by their geomorphic attributes, mainly sinuosity, braiding and erosion/deposition capacity. Utilizing the Nicholas reach classification and extending the process onto the upper Snake River (southern boundary of Yellowstone NP to delta of Snake River into Jackson Lake) seven additional reaches were delineated.

Combining the reach delineations with the vegetation classes, it was possible to determine the extent of beaver habitat within each reach. Table 1 provides a listing of the amount of potential beaver habitat within each reach. Overall, about 44% of the reach areas in Grand Teton NP have the potential to be beaver habitat. However, the maximum distance that a beaver will travel from water to acceptable vegetation browse is 60 m, thus percentage of potential habitat is then reduced to less than 15%. From Table 1 it is clear that there are some reaches that have very little beaver habitat because of a lack of vegetation cover, but this is also the result of a combination of soil characteristics (sand, gravel, and exposed bedrock), associated with sand bars, point bars and steep high slopes of gravel.

Figure 3 provides an over view of the density of beaver colonies by reach over the last 40 years, 1976-2014. By this diagram it is easy to determine that Collins counted the largest number of lodges and bank dens along the Snake River. This disparity in numbers can be attributed to the differences in definition of an active lodge or bank den. Collins counted an active lodge or bank den as any location that displayed any current activity at the time it was located. Thus, even if a lodge or bank den displayed any recent browse droppings when he located the dwelling it was counted as active. There was no differentiation between a location that was used temporarily during the summer or inhabited through the winter. In the aerial surveys of 2006, 2010 and 2014 an active lodge or bank den was counted in late October or early November if it had a food cache. This provided food for the lodge or bank den through the winter and would be a birthing location for the colony in the subsequent spring. The cache census would suffer an approximate 10-15% error in missing caches, but this would not account for the almost doubling of the difference between Collins' counts and the three aerial surveys. Collins, though, believed that the beaver population during his study period, 1974-1976, was probably at the carrying capacity maximum.

The spatial differences between the four different counts displayed in Figure 3 can also be attributed to the fact that Collins did not complete as thorough a survey of beaver colonies in the upper Snake River region, from the southern boundary of Yellowstone National Park to the delta of the Snake River into Jackson Lake. The upper Snake River Reach #6 does display a consistency in having active lodges/dens through the four different censuses. Only three other reaches along the lower Snake River, from the Jackson Lake Dam to Moose, display the same

Table 1. Beaver habitat and vegetation by stream reach.

Reach	Area(ha)	Beaver Habitat	%Reach Area
UpperSnake_Reach1	17.02	1.63	9.59
UpperSnake_Reach2	9.18	0.00	0.00
UpperSnake_Reach3	11.72	0.57	4.88
UpperSnake_Reach4	4.86	0.62	12.72
UpperSnake_Reach5	59.74	17.22	28.83
UpperSnake_Reach6	159.08	77.88	48.96
UpperSnake_Reach7	254.89	127.53	50.03
Upper Snake Total	**516.48**	**225.46**	**43.65**
LowerSnake_Reach1	85.81	31.82	37.08
LowerSnake_Reach2	72.23	12.23	16.93
LowerSnake_Reach3	131.75	29.95	22.73
LowerSnake_Reach4	63.31	6.35	10.02
LowerSnake_Reach5	10.68	2.34	21.93
LowerSnake_Reach6	14.62	1.12	7.67
LowerSnake_Reach7	9.23	2.05	22.19
LowerSnake_Reach8	109.25	15.86	14.52
LowerSnake_Reach9	3.91	0.00	0.00
LowerSnake_Reach10	118.53	26.39	22.27
LowerSnake_Reach11	59.69	39.86	66.78
LowerSnake_Reach12	24.35	21.59	88.64
LowerSnake_Reach13	169.67	109.43	64.49
LowerSnake_Reach14	99.70	67.51	67.71
LowerSnake_Reach15	788.91	294.96	37.39
LowerSnake_Reach16	118.69	52.93	44.59
LowerSnake_Reach17	857.76	454.01	52.93
LowerSnake_Reach18	89.67	59.22	66.05
LowerSnake_Reach19	29.38	20.37	69.33
LowerSnake_Reach20	166.56	108.63	65.22
Lower Snake Total	**3023.70**	**1356.61**	**44.87**
	Total Reach Area (ha)	**Beaver Habitat (ha)**	**%**
Grand Teton NP Total Reach	**3540.18**	**1582.07**	**44.69**

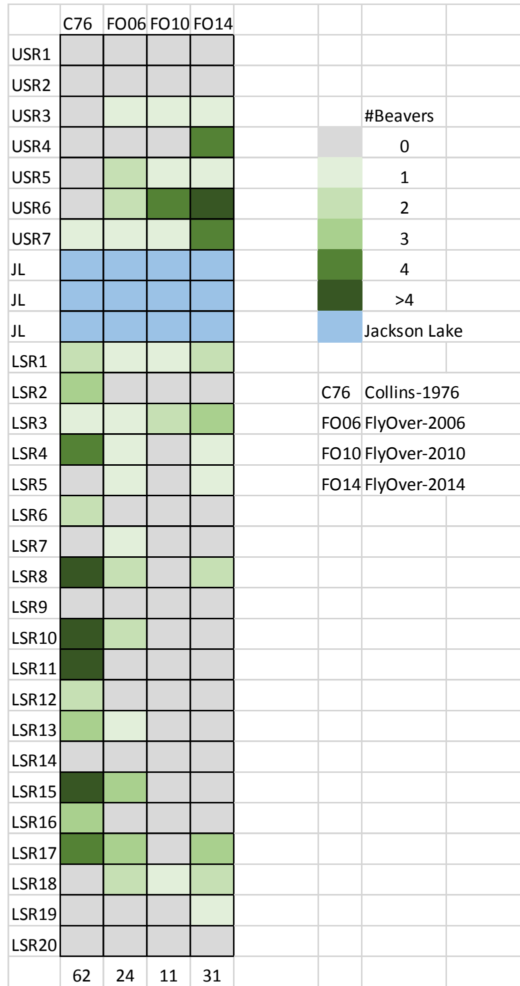

Figure 3. Comparison of beaver locations by reach from field and aerial surveys.

consistency between Collins and the Fly Overs, lower Snake River Reaches #4, #8 and #17. Lower Snake River Reach #4 encompasses the area known as the Oxbow, where there are several bank lodges that have been in the area for several decades and provide for easy access to willows along the shorelines of the oxbow adjacent to the Snake River, providing open water throughout the winter. Reach #8 is an area just downstream from the confluence of the Snake River and Buffalo Fork, an area with a high density of willows adjacent to the Snake River and open water during the winter. Similarly, lower Snake River Reach #17 is a multi-braided area with a high density of willow

The other reaches along the Snake River, both upper and lower reaches, provide intermittent access to the river during the winter period, either because the streamflow is so low that there is too much exposed land between the lodge/bank den and the water or the back channel in which the lodge/bank den is located has no flow during the winter months. Along the lower Snake River at the Moose gauging station the maximum spring runoff flow was 18,150 cfs in June, 1997. In comparison to the minimum winter flow of 641 cfs in March, 2014, a value of only 3.5% of the maximum flow. The radical shifts between spring runoff flows and winter flows make it difficult for beavers to maintain a year-long colony along the Snake River. This winter flow minimum is replicated in the upper Snake River with a maximum flow of 6701.0 cfs in June, 1996 and a minimum flow of 167.7 cfs in September 1994, a decrease of 97.5%.

Climate change will exacerbate this problem into the future. McWethy et al. (2010) has predicted that the middle Rocky Mountain region, which includes the Yellowstone/Grand Teton National Parks, will experience a warming trend and a decrease in winter snow precipitation levels resulting in lower river flows, using a combination of 22 different climate change models coordinated as part of the Coupled Model Intercomparison Project, Phase 3 (CMIP3). For the Central Rockies and the Greater Yellowstone Area, temperatures increased 1-2°C over the last half of the 21st century. Increased winter and spring temperatures have resulted in reduced snowpack, earlier spring snow melts and peak flows. However, the overall records show sizeable variability in temperature and precipitation trends.

This project used the NOAA-Earth System Research Lab's climate base data from 1905-2014 for the climate region WY-Snake Drainage. Figure 4 is the yearly-average temperature for the region, while Figure 5 displays the annual precipitation levels. Though the hottest annual temperature occurred in 1934 at 4.39°C (39.9°F), temperature has slowly increased over this period. The least squares regression illustrating the change in temperature during this time is statistically significant ($F=11.65$, $p=0.000$); however, it is very weak in explaining the variability of the increasing temperature ($r^2=0.097$). However, the trend it portrays has been verified in climate change models (McWethy et al. 2010, Westerling et al. 2011, and Shinker and Bartlein 2012).

A more detailed climatological breakdown of the temperature change by season reveals some difference in rates of change and types of change. The seasons are defined as Winter (Dec, Jan, Feb), Spring (Mar, Apr, May), Summer (Jun, Jul, Aug), and Fall (Sep, Oct, Nov). Figure 6 portrays the seasonal trends for the period of study and illustrates that all four seasons are trending with a slope increase in

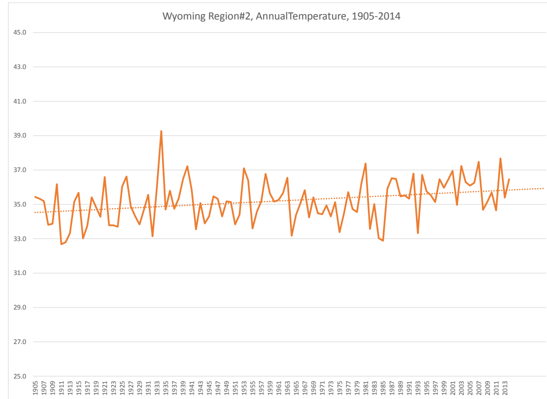

Figure 4. Yearly average temperature, Wyoming Region 2, 1905-2014.

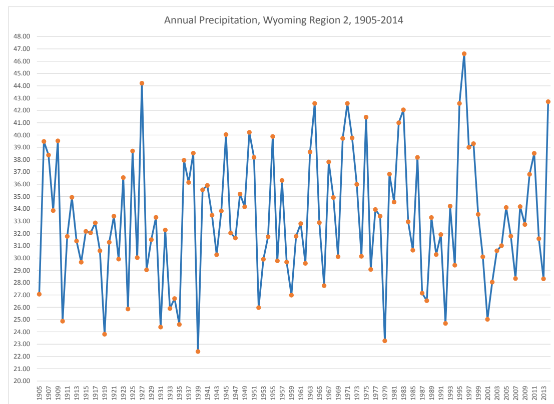

Figure 5. Annual average precipitation, Wyoming Region 2, 1905-2014.

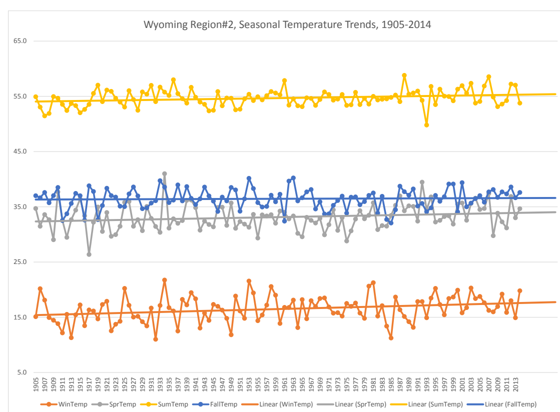

Figure 6. Seasonal temperature change, 1905-2014 (orange = winter; grey = spring; yellow = summer; blue = fall).

temperature, however slowly (Winter: 0.02; Spring: 0.014; Summer: 0.011; Fall: 0.002). Table 2 lists the change in temperature yearly as both an average change over the 110 year period and the average change for the last 30 years (1984-2014). In both the annual yearly changes and the seasonal yearly changes there is a significant difference and increase in change between the 110 years and the last 30 years of record. This identifies the trend that temperature change is occurring at a faster rate in the last 30 years than as a trend for the last 110 years. Again, the GCM (Global Climate Model) multiple models have calculated a 1-4^{o} C increase in temperature into the middle of the 21st century.

Table 2. Average yearly change in seasonal temperature, 1905-2014 and 30-year change 1984-2014.

	Annual	**Winter**	**Spring**	**Summer**	**Fall**
Ave.Chg 1905-2014	0.009	0.043	0.000	-0.011	0.006
St.Dev.	1.594	3.106	3.291	1.949	2.405
30yr Chg 1984-2014	0.114	0.213	0.106	-0.026	0.163

Figure 5 displays the erratic precipitation levels over the last 110 years for the Snake River Region. The annual total precipitation has varied widely over the years. The highest amount recorded in 1997 at 1183.6mm (46.6in) to the lowest in 1939 at 568.9mm (22.4in). However, in the overall statistical realm precipitation is quite normal with a mean of 843.3mm (33.2in), a median of 833.1mm (32.8in), with a standard deviation of only 131.6mm (5.18in) and a mild skewness (0.194) and slight platykurtosis (-0.468). The sinuosity of the diagram makes it difficult to determine if there is a trend in precipitation, however it is a very slight positive trending slope of 0.0172. However, in the GCM inputs there is a slight decrease in precipitation as the temperature warms into the latter parts of the century (McWethy et al. 2010).

The precipitation seasons present the fact that seasonal precipitation levels are distinctly different (Figure 7). Summer precipitation is much lower than the winter precipitation, mean summer precipitation is 129.5mm (5.1in) while winter precipitation is 294.6mm (11.6in). Fall and Spring precipitation are relatively close, at 187.9mm (7.4in) and 231.1mm (9.1in), respectively. As the climate changes the form of the precipitation will also change. McWethy et al. (2010) and Westerling et al. (2011) have found that winter precipitation will change to less snow and more rain and there will be less summer rains increasing the drought potential.

There is a direct relationship between precipitation, runoff and streamflow (Wolman and Leopold 1957, Knighton 1984). In fact, both Vano, Das and Lettenmaier (2012) and Elsner et al. (2014) have demonstrated that temperature and precipitation together influence runoff and streamflow. So that as the trend in precipitation changes so will stream flows. In the Snake River basin the Snake River is divided into two sections, the natural flowing upper Snake River above Jackson Lake and the regulated lower Snake River below the Jackson Lake Dam. For this study, the upper Snake River will be represented by the U.S.G.S. Flagg Ranch gauging station (#13010065, 41º05'56'N, 110º40'03"W), while the lower Snake River will be represented by two gauging stations, one at the dam (Moran, #13011000, 43º51'30"N, 110º35'09"W) and at Moose, WY (#13013650, 43º39'14.6"N,110º42'55.7"W). The Flagg Ranch gauging station has collected hourly data that can be obtained monthly from October, 1983 through September, 2014. Similarly, hourly readings for the Moran gauging station and the Moose gauging station have been acquired from October, 1995 through September, 2014. Figures 8-10 illustrate the monthly flow rates for the three gauging stations, respectively. There is some similarity in patterns of flow, but overall they are distinct. The year 1997 provides the most obvious similarity with high flows at all three locations. This also corresponds to one of the highest years for precipitation (Figure 7).

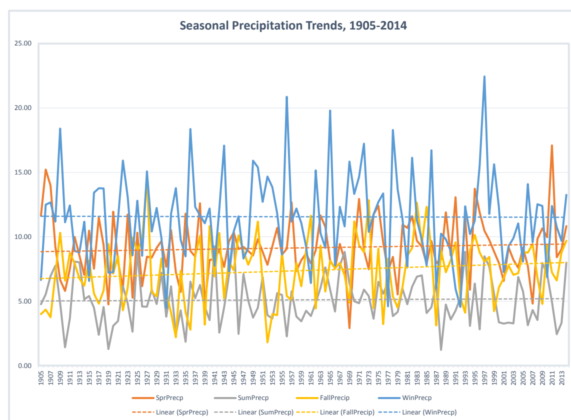

Figure 7. Seasonal precipitation, Wyoming Region 2, 1905-2014.

The upper Snake River represents the natural flow of the Snake River because it has no human interference by diversion, dams, or other storage structures. The average flows by season illustrate a consistent pattern difference with normal variations (Figure 8.). Table 3 lists the major statistical characteristics of the upper Snake River demonstrating the differences between the seasons on the river. Summer is the only season that has a

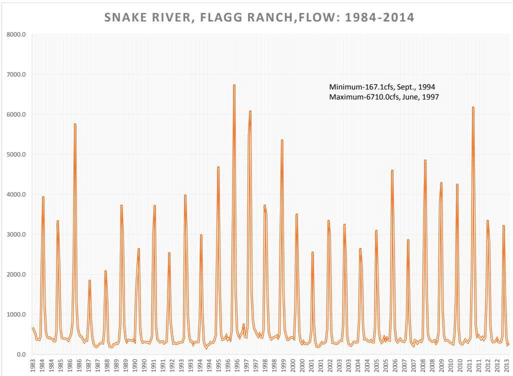

Figure 8. Upper Snake River, Flagg Ranch gauging station streamflow, 1984-2014.

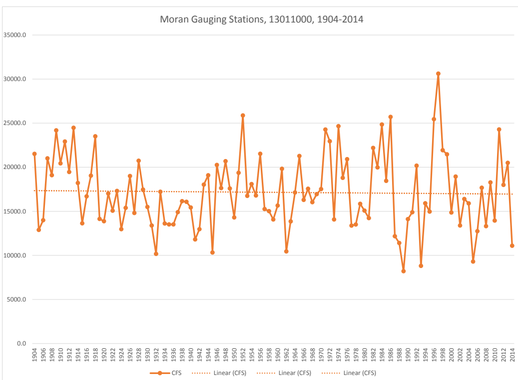

Figure 9. Lower Snake River, Moran gauging station streamflow, 1910-2014.

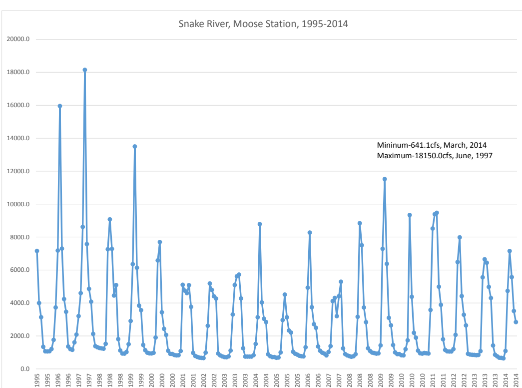

Figure 10. Lower Snake River, Moose gauging station, 1994-2014.

statistically normal distribution, overall the variations in flows even within a season are somewhat erratic as interpreted by their coefficient of variation. The summer season has the highest percentage of variability, 86%. But, as Leppi et al. (2012) have found, August stream flows across the Central Rockies are decreasing with an increase in temperature over the last half of the 20th Century.

The lower Snake River, on the other hand, is a regulated river controlled by the U.S. Bureau of Reclamation since the first dam was constructed in 1906-07. The Moran gauging station has recorded lake discharge from 1904 to the present (Figure 9). However, discharge from Jackson Lake changed in 1957 from a summer demand sequence to a more normal flow with spring and summer snow melt. In reviewing Figure 11 this change is evident by the increases in both winter and spring flows after 1956. Thus, any statistical analysis will only include the years 1957-2014 which are more representative of the flow patterns. Table 4 presents the descriptive statistics for the lower Snake River at Moran for both the annual and the seasonal flows. Summer flows are the highest (8981.2cfs) with winter flows being the lowest (1365.7cfs).

The lower Snake River is a regulated river by the capture and release of water from Jackson Lake. Since 1957 a more normal pattern of flow has been released from the lake, however, at times of repair or reconstruction of the dam flows have been changed. Figure 12 illustrates the changes in the overall storage capacity of Jackson Lake, with an overall capacity of 847,000 a-f. Between 1977 and 1989 the Lake level was lowered because of adjustments and reconstruction of the dam. The lake level follows a yearly cycle of release and storage which impacts on the flow and can be observed in the streamflow levels recorded at the Moran gauging station, just downstream from the Jackson Lake Dam.

The Moose gauging station on the lower Snake River is at the Grand Teton National Park headquarters and represents the lower Snake River before the influences of the city of Jackson. This gauging station, however, reflects the flow changes in the Snake River by recording the combined flows of the Snake River and its three major tributaries: Pacific Creek, Buffalo Fork and Cottonwood Creek. Figure 10 displays the flow rates from 1994-2014. The overall trend has been a steady decrease in the flows on the Lower Snake River. Two of the three natural streams coming into the lower Snake River have recorded decreases in their flows over the last two decades, Pacific Creek and Buffalo Fork (Figures 13-14). Even though their flows have decreased over the last two decades, they are still a major hydrologic impact on the lower Snake River.

Table 3. Descriptive statistics, upper Snake River, Flagg Ranch gauging station, 1984-2014.

	AnnualCfs	*WinCfs*	*SprCfs*	*SumCfs*	*FallCfs*
Mean	10679.94	1037.76	4129.20	4477.98	993.50
St.Error	523.67	36.21	162.39	429.34	50.47
Median	10404.40	977.60	4047.60	3884.40	968.50
St. Dev.	2915.67	201.62	904.17	2390.46	280.98
Kurtosis	0.24	2.35	1.33	-0.39	0.47
Skewness	0.59	1.43	0.46	0.62	0.31
Range	12105.90	894.10	4500.60	8763.70	1323.20
Minimum	6305.60	800.10	2146.00	1292.40	401.20
Maximum	18411.50	1694.20	6646.60	10056.10	1724.40
Coefficient of Variation	27.30	19.43	21.90	53.38	28.28
Count	31	31	31	31	31

Table 4. Descriptive statistics, lower Snake River, Moran gauging station, 1957-2014.

	AnnualCFS	*WinCFS*	*SprCFS*	*SumCFS*	*FallCFS*
Mean	17146.51	1365.70	3665.78	8981.22	3128.76
St. Error	612.366	92.366	359.971	288.152	139.173
Median	16161.35	1234.90	3146.30	8843.00	2921.85
St. Dev.	4663.64	703.44	2741.46	2194.50	1059.91
Kurtosis	0.150	5.932	-0.366	0.041	0.655
Skewness	0.512	2.034	0.803	-0.116	0.509
Range	22416.4	3966.3	9816.5	10089.7	5327.4
Minimum	8208.8	414.0	229.2	3857.3	1117.1
Maximum	30625.2	4380.3	10045.7	13947.0	6444.5
Sum	994497.5	79210.4	212615.4	520910.7	181468.1
Count	58	58	58	58	58
Coeff. of Variation	27.20	51.51	74.79	24.43	33.88

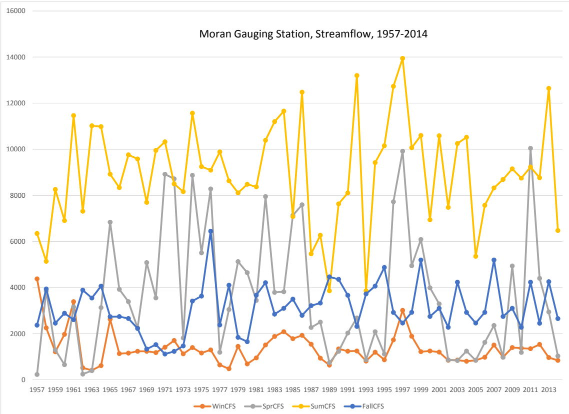

Figure 11. Lower Snake River, Moran gauging station, seasonal streamflows, 1957-2014 (orange = winter; grey = spring; yellow = summer; blue = fall).

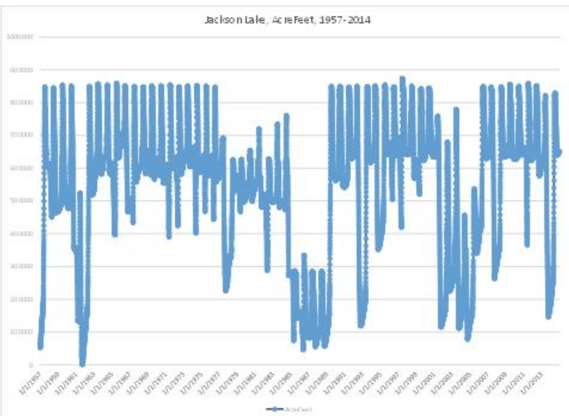

Figure 12. Jackson Lake water capacity changes, 1957-2014.

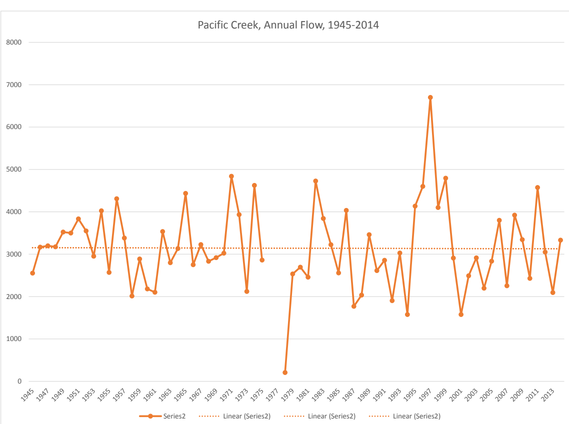

Figure 13. Pacific Creek gauging station, seasonal streamflow, 1945-2014.

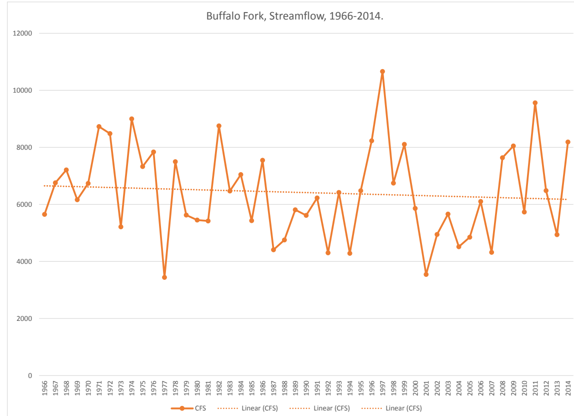

Figure 14. Buffalo Fork gauging station, seasonal streamflow, 1966-2014.

Overall, the hydrologic characteristics of the Snake River basin are currently changing and will continue to change into the future. The climate models have found that the temperatures will be increasing into the middle and later parts of the century and this change will be most noticeable with warmer winter temperatures. This coincides with the fact that precipitation levels will also change and winter snows will decrease while winter rain will increase. This change will impact the flow regime of the Snake River and its tributaries by changing the spring snow-melt runoff. In addition, the climate and hydrologic models have calculated that summers will be warmer and summer streamflows will be less.

The impact of the differences in the Snake River streamflows will have long term effects on beaver spatial ecology. Beavers rely on water as their medium for movement and access to food. If there is no water for beavers to travel to food sources they move to locations that provide that water access. As demonstrated in the work of Collins and found from the aerial beaver census, a slight majority of the beaver lodges/bank dens (60%) are found off the Snake River in back channels and ponds. The Snake River's ebb and flow through summer, fall and winter and then the spring meltoff produces a radical difference in streamflow. This difference between high and low flow changes the distance between lodge/bank dens and the water's edge or depth, increasing the success rate of predators if the water is not deep enough or that distance exposes too much dry land. As the climate changes into the middle of the 21st century, beavers will have to migrate to areas that have permanent water to the bank's edge and depth enough for them to travel, approximately 0.3-0.4m minimum flow depth.

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