CENTRAL PLACE FORAGING CHARACTERISTICS OF BEAVERS (CASTOR CANADENSIS) AND HABITAT MODELING IN GRAND TETON NATIONAL PARK

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Justification and Scope

A significant role of the national park service in the United States is the preservation of pristine landscapes. The natural landscape offers the visitor the opportunity to enjoy the wonders of nature and its processes to create beautiful vistas, soaring mountains, and the interplay of vegetation communities. The visitor to the park can be a passive recreationist and observe the landscape or be an active recreationist and experience the landscape through hiking, biking, mountain climbing and a range of other activities. The key linkage between the active and passive recreationist is the landscape that they are experiencing, in one perspective or the other. Any disruption of that natural landscape diminishes the experience. Unfortunately, the perception of the disruption varies with each individual. The trail to get to a scenic vista can be overlooked by some observers, while others believe it is an example of the devastation of human impact.

Figure 1. is an image of the impact of beavers near Spread Creek. To some observers it is nature's natural landscape, to others the beaver is as devastating to the landscape as a lumber jack is to the forest. The alterations to the landscape made by the beaver are far reaching including not only the cutting down of whole trees for the construction of lodges, but the damming of streams and the creation of ponds and subsequent wetlands. However they are perceived, the importance of beavers to the ecosystem has been identified by a number of authors (Naiman, Melillo and Hobbie, 1986; Naiman, Johnston and Kelley, 1988; Muller-Schwarze and Sun, 2003; and Wright and Jones, 2006).

Figure 1. Beaver tree cuttings near Spread Creek.

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habitats by Lewis Morgan in 1868.   As time has progressed, more in-depth analyses have been completed on a number of aspects of beaver ecology. Two major types of beaver studies focus on their movement and foraging habits. The area of daily and seasonal movements delineates the beaver's territory, which has both a spatial and social component. The size and densities of the territories provide knowledge of the distribution and population of beavers in an area. The social dynamics of the territories can have two dimensions, the intra-colony interactions of parents to their off-springs and sibling relations, and the interaction between colonies that make-up the territories. This research will focus on the spatial aspects of beaver territorial foraging and the determination of beaver movements as they relate to foraging along the Snake River.

The overall problem addressed in this research is to determine the spatial extent and patterns of beaver foraging over the course of a foraging cycle-six to nine months.   By using micro-GPS technology, beaver movements can be captured at a high spatial and time resolution to examine the route, forage-time, and spatial extent of their eating and construction activities.   The micro-GPS technology has the ability to collect up to 60,000 locations providing species coordinates and timeline, thus providing accurate information of their movements and time sequencing.

This research is a continuation of the research proposal submitted to the UW-NPS Research Station last year, 2011-2012. Unfortunately, because of a series of circumstances, none of the objectives were completed, in fact none were even started. The following are the research objectives:

1. Map riparian habitat along the Snake River corridor, focusing on side-channels used by beavers.
2. Document beaver activity and habitat utilization by tracking their movement to and from their lodge, along a particular side-channel, and more broadly within the riverine environment using micro-GPS units.

As mentioned previously, the spatial characteristics of beaver foraging are the main thrust of this project.   Beavers that have built lodges, either along a bank or in a pond/lake, radiate out from that location to forage, and thus are considered central place foragers (Jenkins, 1980). Studies have found that because of the characteristics of their prey species, beaver foraging changes with distance from water (Jenkins, 1980; Belovsky, 1984; McGinley and Whitham, 1985; Gallant, et al., 2004; and Raffel, et al., 2009). That generally, the foraging species increase in size with distance from water, either a lake or pond. Raffel, et al. (2009) along with Pinkowski (1983) and Gallant, et al., 2004) found that not only were there size differences with distance, but also species selectivity. Thus, the overall foraging by beavers has an impact on the vegetation density and composition (Donkor and Fryxell, 1999; and Barnes and Mallik, 2001). These changes can then have an overall impact on the ecosystem if sustained over a long period of time.

A typical central place study will locate the lodge that is the home of the beaver colony and survey vegetation species from that location noting type and foraging activity.   In the study by Raffel, et al., (2009) they completed a survey of beaver activity around the lake and identified eight foraging sites with beaver cuts less than 2 years old. The research team delineated the sites by the extent of foraging and then recorded information on all of the tree species (>1cm in diameter) within the foraging area, distance from shore, cut status and stem/trunk diameter (2009, 65). Their analysis consisted of modelling the preferred foraging species and relating this to size, distance from shore and distance from the lodge. Overall, this aspect of the Grand Teton NP beaver foraging has been completed for several select sites (Gribb and Harlow, 2011).

This research has two major distinctions from the cited research. First, there has only been one central place foraging study along a western US river system. McGinley and Whitham (1985) examined the central place foraging of beavers along the San Juan River, UT. They specifically focused on cottonwoods (*Populus fremontii*) and only in one select location. Breck, Wilson and Anderson (2001) were not specifically examining central place foraging, but they did study beaver home range along the Yampa and Green Rivers. The focus of this beaver research was originally designed to address movements along the Snake River, addressing beaver foraging along a western river, an aspect that has not been fully examined. Second, this study captured beaver movement with the micro-GPS unit, a process that has never been attempted. Not only were the foraging locational patterns recorded, but also foraging times. Fryxell and Doucet (1993) recorded this same type of information with beavers in an enclosure using visual observations, but they provided pre-cut tree stems and embedded them into the soil to determine foraging selection, times and distances. This study recorded real foraging times and movement coordinates in a natural environment.

Significance

This project has three points of significance. First, this is a technological innovation project attaching a micro-GPS unit to beavers. This had not been attempted before, and the process and procedures were recorded to provide a framework upon which to build additional research in this technique.   In the work of Raffel et al., (2009) the researchers GPS'd the activity areas of the beaver and did their calculations all after the fact.   Several studies have fixed a radio telemetry unit to the tail of the beaver and systematically monitored their locations using telemetry (Rothmeyer, McKinstry and Anderson, 2002; McNew and Woolf, 2005; and Bloomquist and Nielsen, 2010). The shortcoming of this technique is that the location and movements between telemetric readings is unknown, the only location information collected is at the times and days selected by the researchers, thus a biased sampling of activities and movement are collected. The micro-GPS unit had the capability to capture a signal at a set time interval, every 5 minutes, thus allowing a systematic sampling of beaver locations (www.telemetrysolutions.com) over the entire research period. In this case, the research period was only from May 26-June 2, 2013. One

known shortcoming of this system is that GPS signals generally does not penetrate water to a depth of more than 20cm. In a sample test with a hand-held GPS, locations underwater were collected to a depth of 1m (Gribb, unpublished 2011). However, the hand-held GPS unit had a much larger antenna then the unit attached to our test beaver. The unit used in this study was only 52mm(w) x 78mm(l) x 28mm(h). The signal was lost as the beaver entered/exited the lodge or swam in deeper water. In addition, the signal was lost while the beaver was in the lodge.

The second point of significance for this study is that it provides a detailed record of the extent of beaver foraging, though for only a short time period (May 26-31) in the Spread Creek meadow pond complex in Grand Teton NP. The resolution of the location and movement data provides the detail that is needed to determine home range and colony territory. This study recorded the movement of the beaver in a pond area that encompasses approximately 11ha with a complex of 20 ponds, with 10 greater than .03ha and 10 less than .03 ha. The captured location data allows the researchers to calculate the distances travelled, frequency of pond use, the frequency of water way use, and the proportion of time on each pond. This type of information has not been recorded for any western ponds, a dominant feature for beaver habitats in the mountainous western U.S.

The third point of significance is the building of a beaver habitat model that incorporates a range of data for a riverine habitat. Most models utilize either a pond site/situation (Gallant, Berube, Tremblay and Vasseur, 2004) or a broad area approach (Slough and Sadlier, 1977; Allen, 1983; Howard and Larson, 1985; Beier and Barrett, 1987; South, Rushton, and Macdonald, 2000; Beck and Staley, 2005; Maringer and Slotta-Bachmayr, 2006; Cox and Nelson, 2006; Frantisek and Kostkan, 2009; and Bird, et al., 2013). This model is based on a combination of remote sensed data of vegetation with digital data on topography, soils, and stream reach delineations. The Snake River has two significant components, the portion above the Jackson Lake Dam and the portion below the Jackson Lake Dam. The portion above the dam is unrestricted and natural, whereas the portion below the dam is significantly impacted by releases of water held by the Jackson Lake Dam. The examination of beaver habitat along a river in the western United States has been limited (Slough and Sadleir, 1977; Howard and Larson, 1985; Breck, et al., 2003; Bryan, et al., 2013). This habitat model relies on the stream density, vegetation, soils and slope factors to determine the potential habitat along the Snake River stream reaches.

Methodology

The general strategy of the central place foraging investigation is to characterize beaver riparian ecology by an inventory of the foraged vegetation and the monitoring of an individual beaver using a pair of tracking methods, and to integrate these two sources of information to provide insight on physical factors influencing beaver behavior patterns. Our study involved a combination of geospatial data analysis and field work, and each of

these components is described in the following sections. The project initially proposed to examine three specific beaver habitats: a segment of the Snake River adjacent to the Bar BC Ranch with backwater tributaries; a segment of the Snake River 5km downstream from the Flagg Ranch bridge without a backwater tributary; and a beaver pond sequence along Spread Creek, 1km east of US26/US98/US191. Each of these locations had active beaver lodges and displayed active foraging.

To understand beaver habitat utilization and movements, a systematic method of collecting beaver locational data was needed.   The first task is to locate, live-trap and attach a micro-GPS unit on a beaver.   Because this is a pilot project to test the use of a micro-GPS unit, one beaver would be captured at each of the three pilot locations, fitted with the device and released. To make recovery of the GPS unit easier and to test the procedure for capturing, attaching the unit and collecting data afterwards, a beaver was trapped first at the Spread Creek ponds complex. Trapping of the beaver was accomplished by a team composed of experienced wildlife handlers, Dr. H. Harlow (UW, Dept. of Zoology and Physiology) and Drew Reed (formerly Wyoming Wetland Society), May 26, 2014.   To facilitate handling and reduce the capture trauma, the beaver was anesthetized using the process described by McNew, et al. (2007).   A measured dose of ketamine hydrochloride and xylazine hydrochloride was administered with appropriate lag time for recovery before release.   All UW, AMS, NPS, and USDA wildlife handling guidelines procedures were followed (Appendix A, UW IACUC permit).   A portion of a small GPS device (80mm x 10mm x 10mm) was glued to the beaver tail and another part of the unit was belted to the base of the beaver tail. This would allow flexibility of tail movement and the aerodynamic design of the GPS will minimize the possibility of the unit being caught-up on vegetation and underwater debris. In addition, a radio-telemetry devise as a component of the micro-GPS was activated at the same time as the GPS unit

To accomplish our research objectives, the micro-GPS unit attached to an adult beaver can possibly collect the coordinates of their movements for six months. Because the GPS uses a set time interval between location recordings (every 5 minutes upon connecting to the GPS-satellite network) detailed movements are possible. Finally, the radio-telemetry antenna assisted in locating the beaver to download the GPS data, allow for re-capture and removal of the micro-GPS. According to Bryan Bedrosian, Beringia South, data can optimally be downloaded within a radius of 400 m from the GPS unit.   However, if the beaver has moved from its lodge it will be critical to locate the beaver and retrieve the data from the micro-GPS, thus a vhf radio telemetry unit is built into the micro-GPS unit. All necessary procedures were followed to ensure that the recording devices and study area were not disturbed nor impact recreationists. The pilot study areas were selected because of their locations away from river recreationists- rafters and fishermen and the general tourist-public.

To map the terrain and riverine characteristics of the Snake River required combining field data, remote sensed data and digital environmental data. Objective #2 is to examine and analyze the interrelationships between these different data sets to produce the appropriate maps and a new, more robust beaver potential habitat model. The field and remote sensed data have been described previously, the environmental factors were derived from GTNP, USGS, and UW WyGISC data sets on topography, hydrology, vegetation, soils, and geology. The integration of these different types of data sets provided a model that is multi-dimensional and dynamic, parameters that Shenk and Franklin (2001) thought critical to any natural resource management modeling. The remote sensing and river morphological measurements that were the main components to the habitat model. This integration of data sets incorporated the use of multi-dimensional spatial analysis to determine the statistical significance of the different field measurements, environmental factors, and remote sensed imagery in the construction of the new habitat model.

Project Results

Mapping the Snake River corridor for beaver habitat involved compiling the appropriate spatial datasets from a variety of sources. The appropriate datasets for identifying beaver habitat can be categorized into five major components as identified by a number of researchers (Slough and Sadlier, 1977; Allen, 1983; Howard and Larson, 1985; Beier and Barrett, 1987; South, Rushton, and Macdonald, 2000; Beck and Staley, 2005; Maringer and Slotta-Bachmayr, 2006; Cox and Nelson, 2006; Frantisek and Kostkan, 2009; and Bird, et al., 2013); water, landscape, vegetation, soils, and anthropogenic factors. The water component details the characteristics of the water system; water flow, stream order, stream characteristics (width, depth, stream reach length), stream reach, stream gradient, bank height, floodplain width, wetlands, pond size, braiding, and sinuosity. The landscape factors generally relate to topography, slope and orientation. Vegetation has a number of different factors that are examined including species, communities, species/communities a set distance from water, tree and shrub density, tree diameter breast height, tree and shrub canopy cover, shrub height, shrub stem size, browse/cutting evidence, and . Soils information is generally texture and depth, especially a set distance from water. Anthropogenic factors are distance to residential/commercial development, river engineering (dams, levees, channelization, and bank stabilization), road density, and farming.

This project did not utilize all of the factors, but did employ parts of four of the five components. The water component consisted of the main hydrology of Grand Teton National Park at the HUC 12-level and the identification of all lakes and ponds (over .25ha). Another aspect of the water component entailed using the river reaches delineated by

Nelson (2007) and modifying their boundaries to correspond with the Snake River floodplain. The river reaches were used as the main spatial units for analysis because of the geomorphic characteristics they portray. The vegetation component consisted of the spatial distribution of the specific species communities, in this case willows (*Salix spp.*) and cottonwoods/aspens (*Populus spp.*), the two main species consumed by beavers in Grand Teton National Park (Collins, 1977). Soil texture is a key for beavers building bank dens along the Snake River channel, but not as important for bank lodges in the backwater tributaries. Finally, the anthropogenic factor that is the most dominant in Grand Teton National Park is the Jackson Lake dam. To accommodate the influence of the dam, the Snake River is divided into two portions, the Upper Snake River (15.9km) and the Lower Snake River (43.4km) with the dam as the separator. The other anthropogenic factors are not considered in the modeling.

General descriptors of the Snake River corridor provide a needed background for the project overall. The topography and slope of the Snake River is not as dramatic as most streams. The northern reach of the Snake River at the southern border of Yellowstone National Park has an elevation of 2091 m and this flows into Jackson Lake with a normal elevation of 2064.6m, thus the Upper Snake River gradient over this 16.2km stretch is only 0.17%. The southern reach from Jackson Lake Dam (2064.6m) to Moose (1969m) is 42.9km and has a gradient of 0.23%. The low gradient provides an environment in which the Snake River has the potential to create significant braided streams with a large sinuosity index.

The Snake River was divided into 27 reaches, 7 reaches on the Upper Snake River above Jackson Lake and 20 reaches from Jackson Lake dam to Moose (Nelson, 2007). Defining aspects of each reach related to the geomorphic characteristics of the stream channel; sinuosity, braiding, confluence, width/depth, floodplain and gradient. Figure 2. Illustrates the delineation of the reaches. The average reach is approximately 121.2 ha, however, there is a significant difference between the area of the Upper Snake River reach and the Lower Snake River reach, 35.5ha versus 151.2ha respectively. The Upper Snake River flows through a narrow canyon for almost one-half of its distance, whereas the Lower Snake River spreads out across the Snake River valley below the Dam. Both sections of the river, however, are similar in average reach stream length 2296.9m and gradient 0.20%.

Vegetation along with Snake River was identified and delineated by the Grand Teton National Park using 2005 NAP photography at a resolution of 1m. This data was up-dated using 2012 NAP photography at the same resolution. The updates were generally associated with the meandering of the Snake River and the increase/decrease or elimination of sand bars and movement of vegetation along cutbanks. Two major categories of vegetation were distinguished, communities of *Salix spp.* and *Populus spp.*. These two major communities were formed by combining the following vegetation classes:

Salix spp includes Salix spp. Shrubland; *Populus spp.* includes Populus tremulides Forest, Mixed Conifer-Populus spp., Populus angustifolia-Populus balsamifer Riparian Forest, and Populus tremuliodes Woodland Regenerated. Table 1 provides an overview of the proportion of each major beaver habitat vegetation community by reach.

The soil component of the model was derived from the U.S. Soil Service Soil Survey of Teton County, Wyoming Grand Teton National Park Area and the digital SSURGO data files of the Natural Resources Conservation Service. Along the Snake River below the Jackson Lake Dam, the dominant soils are the Tetonville gravelly loam, Tetonville complex, Tetonville-Riverwash complex and assorted Tetonia-Lantonia and Taglake-Sebud associations. As the Snake River meanders through the valley there are cyclical occurrences of sandbars and cutbanks, braided stream and straight bank stream. Intermittently the Snake River cuts into the older stream terraces and creates a high bank, steep slope gravel, cobble and sand embankment.

The overall result of the multi-factored analysis is a map of potential beaver habitat along both portions of the Snake River. The potential beaver habitat accounts for only xxx% of the Snake River corridor, limited by the vegetation communities and the extensive braiding in several river reaches (Figure 3). Major portions of the river's bank conditions are not suitable for bank dens or bank lodges because of the high percentage of cobbles, gravel and sand. In addition, the alternating sand bars and cut banks do not offer areas suitable for dens or lodges.

The second objective of this project was concerned with documenting beaver activity areas, central place foraging. The initial intent was to attach a micro-GPS unit to a beaver and track its movements over six months. Three beaver activity areas were selected to conduct this original research; two locations on the Snake River (one on the Upper Snake River and one on the Lower Snake River) and one site in the Spread Creek pond complex. To test the procedure for live capturing, anesthetizing, attaching the GPS and downloading the location data, the Spread Creek pond complex was selected for ease of access and limited range of the beaver. On May 26th the unit was attached to a 21.8kg beaver. The unit stayed attached until May 31st, with the collection of 128 UTM coordinate points. Figure 4 displays the distribution of the recorded positions, with an overall central foraging area of 11ha. There is a complex of 20 ponds with 10 > .03ha and 10<.03ha. Table 2 provides a listing of the descriptive statistics for each day of activity and the overall descriptive statistics. May 26-27th the beaver did not venture far from the lodge, averaging only 57.2 meters from the lodge. However, from May 28th until May 31st the average distances increased to 122-154m. with an average coefficient of variation of 41.42%. On May 31st at 05:30am the micro-GPS unit became detached from the beaver, both the glue and the strap failed. The micro-GPS unit was retrieved using the VHF signal.

Descriptive spatial statistics portray the distribution of foraging by the tagged beaver. Using ring-sector analysis it is possible to analyze the spatial distribution of foraging at the Spread Creek Pond complex. Table 3 displays the number of point locations per ring/sector from the lodge, with element (Ring-2, Sector-3) containing 38 points (29.9%) of the 127 point total. This element has a high density of willows and easy access from one pond to another (Figure 5). A constraint in their foraging is a high embankment (5m) approximately 100m from the lodge and oriented NW-SE. This is evident by the fact that over 80% of the points are in sectors 8, 2 and 3. This embankment separates the meadow-pond complex from the surrounding outwash plain.

On June 26, 2013 another attempt was successful to live trap a second beaver (23.2kg) and attach a micro-GPS unit. A modification was made to the strap to strengthen its attachment to the GPS unit, the point of failure in the first attempt.   Unfortunately, the unit was lost within one day of attachment. A VHF signal could not be located, and thus the unit was lost.   Two attempts were initiated to recapture another beaver and after ten days the traps were removed.   In addition, traps were setup along the Lower Snake River to capture a river beaver, similarly, after 10 days with no capture the attempts were abandoned.

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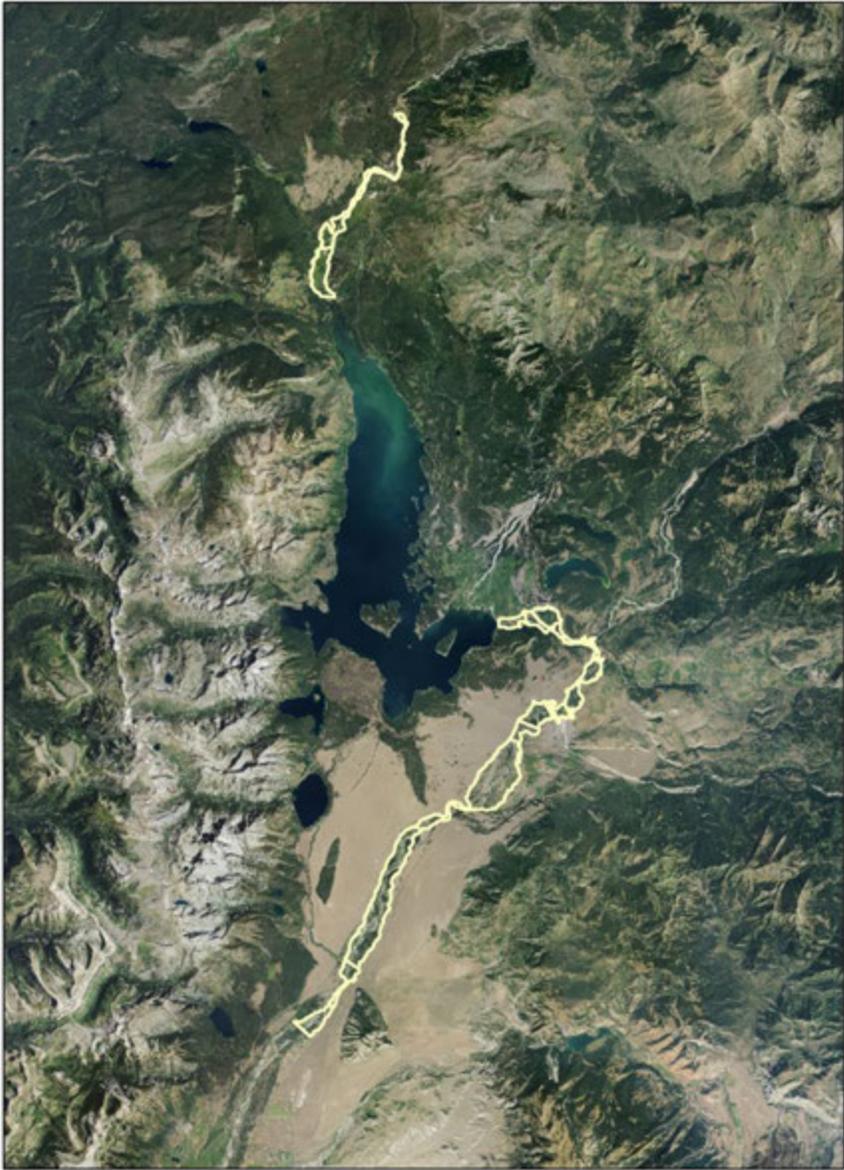Figure 2. Upper and Lower Snake River Reaches.
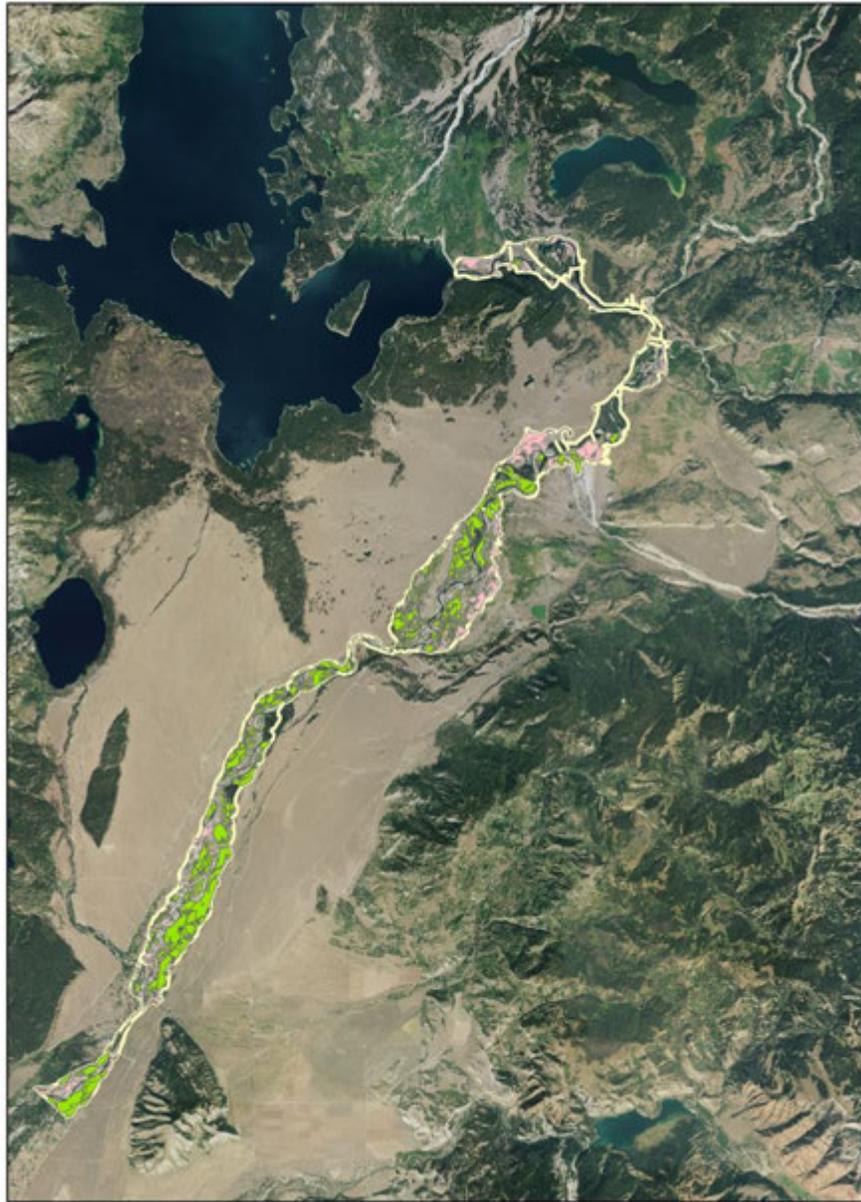
Figure 3. Lower Snake River Potential Beaver Habitat.

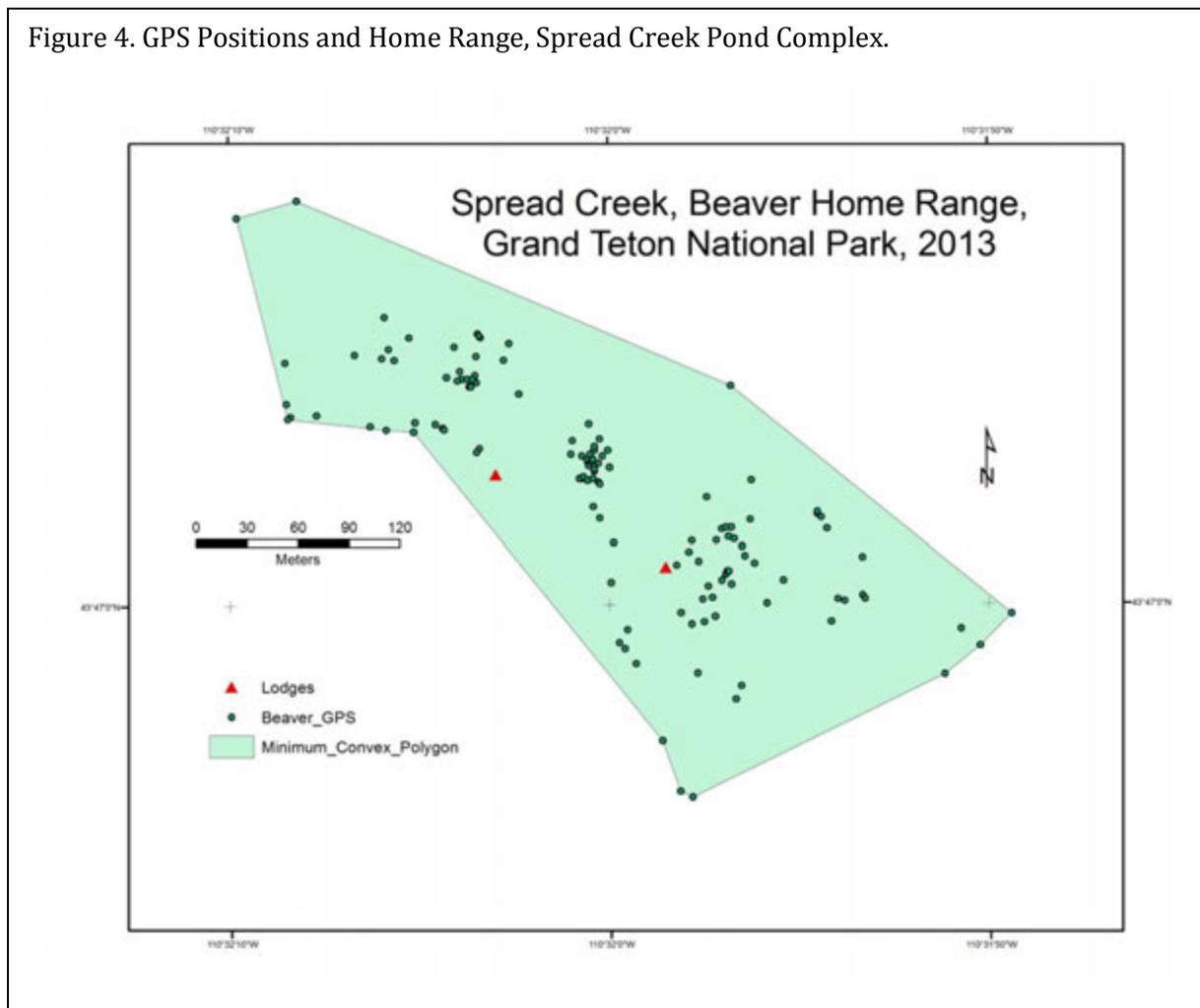Figure 4. GPS Positions and Home Range, Spread Creek Pond Complex.

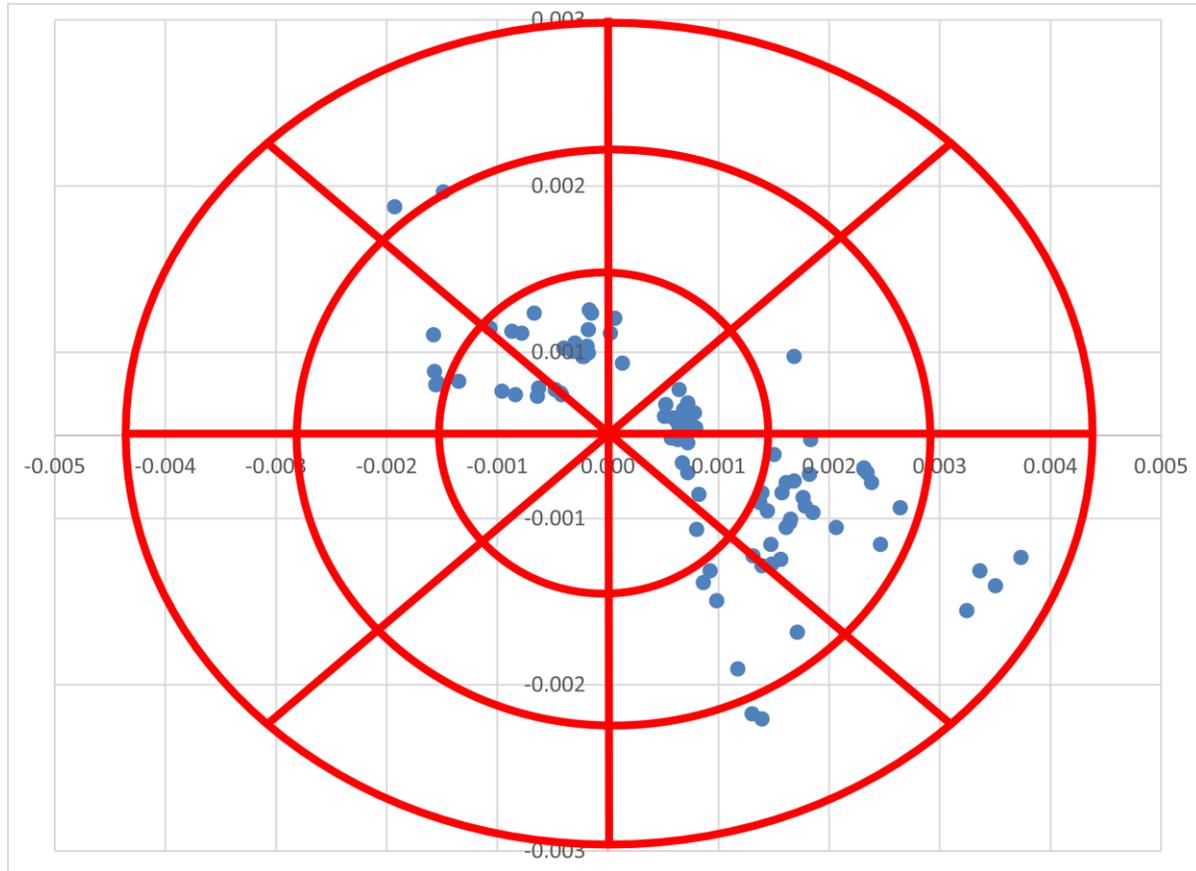Figure 5. GPS Positions, Ring-Sector Analysis, Spread Creek Pond Complex (scale: .001=115m).

Table 1. Vegetation Communities by Reach.

Reach	Area(ha)	Salix spp.(ha)	%Reach	%SR Total	Populus spp.(ha)	%Reach	%SR Total
UpperSnake_Reach1	17.02	1.63	9.59	0.74	0.00	0.00	0.00
UpperSnake_Reach2	9.18	0.00	0.00	0.00	0.00	0.00	0.00
UpperSnake_Reach3	11.72	0.57	4.88	0.26	0.00	0.00	0.00
UpperSnake_Reach4	4.86	0.62	12.72	0.28	0.00	0.00	0.00
UpperSnake_Reach5	59.74	17.22	28.83	7.78	0.00	0.00	0.00
UpperSnake_Reach6	159.08	73.67	46.31	33.30	4.22	2.65	100.00
UpperSnake_Reach7	254.89	127.53	50.03	57.64	0.00	0.00	0.00
Upper Snake Total	516.48	221.24		42.84	4.22		0.82
LowerSnake_Reach1	85.81	27.39	31.92	6.44	4.42	5.15	0.48
LowerSnake_Reach2	72.23	7.78	10.78	1.83	4.45	6.16	0.48
LowerSnake_Reach3	131.75	23.99	18.21	5.64	5.96	4.52	0.64
LowerSnake_Reach4	63.31	6.35	10.02	1.49	0.00	0.00	0.00
LowerSnake_Reach5	10.68	1.95	18.23	0.46	0.40	3.70	0.04
LowerSnake_Reach6	14.62	0.46	3.15	0.11	0.66	4.52	0.07
LowerSnake_Reach7	9.23	1.39	15.03	0.33	0.66	7.16	0.07
LowerSnake_Reach8	109.25	15.08	13.80	3.54	0.79	0.72	0.08
LowerSnake_Reach9	3.91	0.00	0.00	0.00	0.00	0.00	0.00
LowerSnake_Reach10	118.53	21.40	18.05	5.03	5.00	4.22	0.54
LowerSnake_Reach11	59.69	29.68	49.72	6.97	10.18	17.06	1.09
LowerSnake_Reach12	24.35	6.57	26.99	1.54	15.01	61.65	1.61
LowerSnake_Reach13	169.67	59.56	35.10	14.00	49.87	29.39	5.36
LowerSnake_Reach14	99.70	3.31	3.32	0.78	64.20	64.39	6.90
LowerSnake_Reach15	788.91	77.37	9.81	18.18	217.59	27.58	23.37
LowerSnake_Reach16	118.69	2.51	2.12	0.59	50.41	42.48	5.41
LowerSnake_Reach17	857.76	86.14	10.04	20.24	367.87	42.89	39.51
LowerSnake_Reach18	89.67	21.70	24.20	5.10	37.53	41.85	4.03
LowerSnake_Reach19	29.38	10.11	34.39	2.37	10.27	34.94	1.10
LowerSnake_Reach20	166.56	22.82	13.70	5.36	85.81	51.52	9.22
Lower Snake Total	3023.70	425.55		14.07	931.06		30.79
Grand Teton NP Total	**3540.18**	**646.79**		**18.27**	**935.28**		**26.42**

Table 2 Descriptive Statistics of GPS Positions Distance to Lodge by Day.

Overall Description		May26-27	May27-28	May28-29	May29-30	May30-31
Mean	113.12	57.20	154.14	122.87	148.16	137.92
Standard Error	5.82	1.57	18.79	13.25	7.41	13.47
Median	100.81	57.68	135.88	132.07	145.59	146.54
Standard Deviation	65.84	10.28	88.11	57.75	34.74	63.16
Coefficient of Variation	58.20	17.97	57.16	47.00	23.45	45.79
Kurtosis	0.57	0.40	-0.48	-0.87	1.09	-0.26
Skewness	0.93	0.48	0.70	0.13	-0.18	-0.32
Range	311.52	47.26	287.84	193.31	155.55	221.22
Minimum	15.36	39.35	39.04	37.87	64.55	15.36
Maximum	326.88	86.61	326.88	231.17	220.11	236.58
Count	128.00	43.00	22.00	19.00	22.00	22.00

Table 3. Ring-Sector Analysis, Spread Creek Pond Complex.

GPS Location Frequency

Rings	Sectors								Total	%
	1	2	3	4	5	6	7	8		
1	3	19	16	3	0	0	12	24	77	60.6
2	0	1	38	4	0	0	2	1	46	36.2
3	0	0	4	0	0	0	0	0	4	3.1
Total	3	20	58	7	0	0	14	25	127	
%	2.4	15.7	45.7	5.5	0.0	0.0	11.0	19.7		100