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Landscape and Habitat Attributes Influencing Beaver Distribution

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LANDSCAPE AND HABITAT ATTRIBUTES INFLUENCING BEAVER DISTRIBUTION

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EXECUTIVE SUMMARY / ABSTRACT

Removal of beaver across the North America landscape from the 1600s through the 1800s has played a major influence on the alteration of stream and riparian resources. Degradation of riparian habitats has negatively impacted many wildlife and fish species, including species listed under the Endangered Species Act. The ability of beavers to modify stream ecosystems offers a unique opportunity to restore these habitats. Many private and government agencies are working towards using beaver as a restoration tool, not only for better functioning ecosystems but also to benefit humans. Taking the big picture look, beaver and their ability to modify the environment are viewed by describing the ecological benefits and impacts to stream ecosystems and influences on fish habitat and populations; analyzing landscape and habitat attributes influencing beaver distribution using data from a large scale stream and riparian monitoring program (Pacfish/Infish Biological Opinion Effectiveness Monitoring (PIBO EM); the human dimension aspects and how beaver can be used to benefit humans in a sustainability framework; the economic incentives of using beaver for stream restoration; and, policies, laws, and administrative considerations associated with beaver.

PIBO EM Preliminary data from PIBO EM suggests that as beaver populations make a comeback they will occupy a diverse range of habitats. The data demonstrates that beaver occupy a wide range of landscape characteristics and site habitats, but particular attributes are more important than others in determining where beaver are present. The overlap of so many landscape, site, and vegetation attributes between sites with and without beaver activity and given the vast majority of PIBO EM sites are currently without beaver, indicates that many areas may already be suitable for beaver occupation, providing optimism for beaver restoration opportunities. Many groups and organizations are spending money, effort, and time into developing habitat criteria and habitat suitability indexes for beaver reintroductions. Collaborative efforts with PIBO EM would offer data and information from a large geographical area, saving valuable resources to be used for more effective beaver management. Although beaver populations have been affected by removal from trapping and loss of habitat through urbanization, as beaver populations increase they will occupy much of their former range, restoring degraded habitats for the betterment of both mankind and fish and wildlife.

INTRODUCTION

Historically, North American beaver (*Castor canadensis*) were found in greater numbers and distribution than present and influenced the structure and function of streams, riparian areas, and fish and wildlife populations (Baker and Hill 2003). The ecosystem role and landscape influences of beaver are becoming increasingly understood and accepted (Kemp et al. 2011). As the awareness of the influence beavers have on ecosystems continues to grow, so does interest from land managers on beaver abundance and spatial distribution, factors influencing their distribution, and how beaver reintroductions can be used as a restoration tool to restore degraded habitats and ecosystems (Pollock et al. 2011). Beaver restoration is becoming a popular tool for land managers and is currently being explored as a method of contributing to water storage and combating global warming (Walker et al. 2010; Bird et al. 2011), restoring lost or degraded ecological functions (Pollock et al. 2011), increasing fish and wildlife habitat (Pollock et al. 2004; Amish 2006), and aid in wetland development (Hood and Bayley 2008).

Prior to the arrival of Europeans, the beaver population in North America was estimated to be between 60 and 400 million individuals (Seton 1953; Naiman et al. 1988), occupying a broad spectrum of ecoregions from subtropical to subarctic and occurring coast to coast throughout most of North America (Figure 1). As eastern beaver populations declined from overharvest, expeditions were often made to the west (1800-1850), solely for the purpose of discovering new trapping areas (Cline 1974; Kay 1994). Eventually western regions were also overharvested (Johnson and Chance 1974), and by 1900 beaver were nearly extirpated from North America (Jenkins and Busher 1979). Geomorphology and plant communities of small low-gradient streams were changed throughout much of the Northern Hemisphere after reduction of beaver populations (Rea 1983; Naiman et al. 1988). Recent population estimates range from 6 to 12 million (Naiman et al. 1986) and there has been widespread recognition that beaver dams play a vital role in maintaining and diversifying stream and riparian habitat (Naiman et al. 1988; Pollock et al. 1994; Gurnell 1998; Collen and Gibson 2001).

The elimination of beaver from portions of its historic range has been cited as a major influence on the change in structure and patterns of vegetation in riparian ecosystems (Barnes and Dibble 1986; Naiman et at. 1986, 1988; Kay 1994; Pollock et at. 1995). Watershed restoration is a key component of many land management plans and endangered species recovery efforts on public and private lands. Millions of dollars are spent annually in individual river basins in an effort to enhance or restore habitat for salmonids and other fish species (NRC 1996). It is estimated that at least $14 to $15 billion has been spent on restoration of streams and rivers within the continental United States between 1990 and 2005 (Bernhardt et al. 2005). This increased interest and funding is, in part, due to increased listings of Pacific salmon *Oncorhynchus* spp. and steelhead *Oncorhynchus mykiss* stocks as threatened or endangered under the U.S. Endangered Species Act (ESA). There have been many studies documenting the use of beaver ponds by a variety of fish species and the loss of beaver pond habitat has been documented as a major reason for the decline of certain fish species, including those listed under ESA (Pess et al. 2002; Pollock et al. 2004; Hood 2012). The unique ability of beaver to modify stream ecosystems and store water, trap sediment, reduce channel erosion, and enhance establishment and production of riparian vegetation can be used as a passive management tool to restore degraded streams and riparian habitat, providing habitat for a diversity of species, including fish listed under ESA.

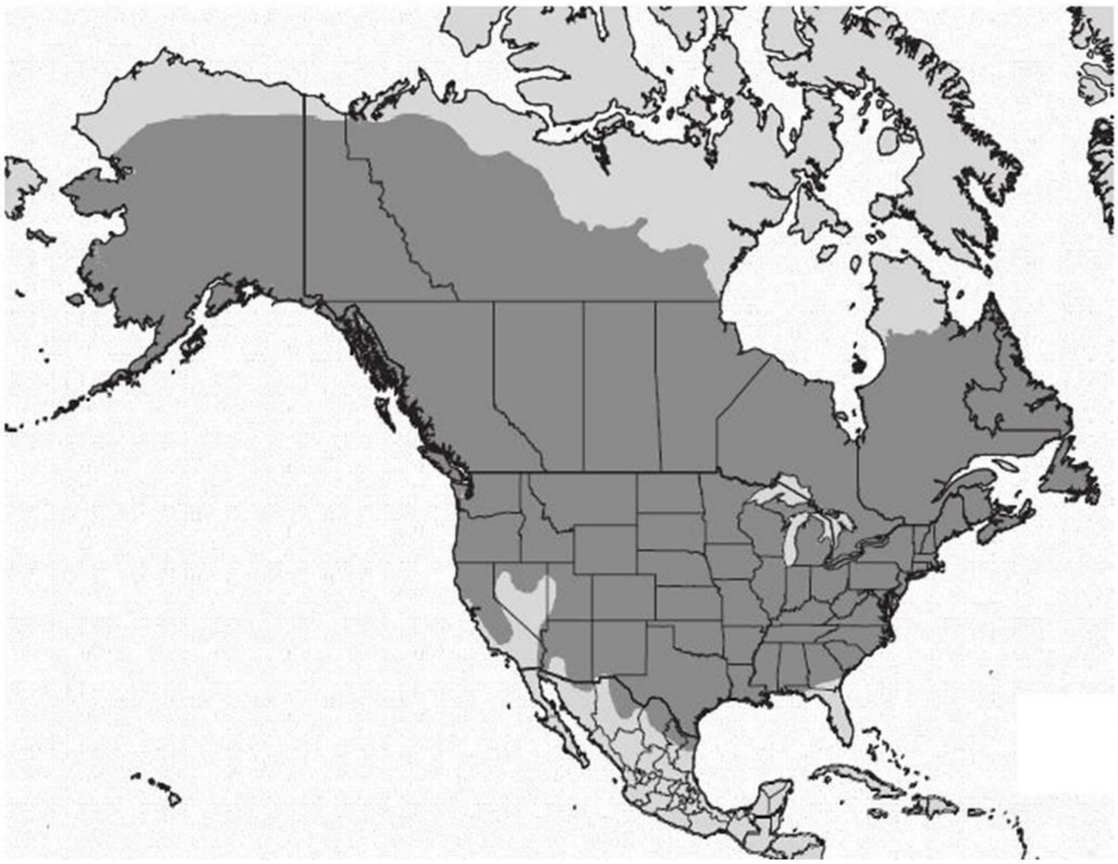

Figure 1 – Estimated current and historic distribution of beaver in North America. Current and historic distributions are approximately coincidental. (Based on Jenkins 1979; MacDonald et al. 1995; Halley and Rosell 2002)

CORE COMPETENCY – ECOLOGY

BEAVER AS A KEYSTONE SPECIES: IMPACTS TO STREAM ECOSYSTEMS AND INFLUENCES ON FISH HABITAT AND POPULATIONS

INTRODUCTION

Keystone species are those that play a critical role in the structure, function, and processes of an ecological community; having direct and indirect effects on both the landscape and the biota that live in the landscape. The role keystone species play is so important that ecosystems can undergo dramatic shifts if they are removed (Estes and Palmisano 1974; Naiman et al. 1988). Beaver are considered ecosystem engineers and can modify the landscape, influencing both the abiotic and biotic environment in which they live (see Collen and Gibson 2001; Rosell et al. 2005). Beaver's unique ability to modify the landscape and the importance of beaver activity to a variety of species make them a keystone species (Naiman et al. 1988). Habitat alterations on aquatic systems change the availability and quality of habitat for a variety of species, including fish, and can have population level impacts. As a keystone species, beaver influence habitat quality and the amount of habitat available to fish, which impacts fish populations (Snodgrass and Meffe 1998; Schlosser and Kallemeyn 2000; Pollock et al. 2004).

BRIEF HISTORY ON THE TERM 'KEYSTONE SPECIES'

The term 'keystone species' was coined by zoologist Dr. Robert Paine in 1969 and was based on research he conducted in rocky intertidal marine habitats in Mukkaw Bay, Washington on the relationship between the purple seas star/starfish (*Pisaster ochraceus*) and the common mussel (*Mytilus californianus*). In Dr. Paine's 1969 paper, *A note on trophic complexity and community stability*, he stated, "the species composition and physical appearance were greatly modified by the activities of a single native species high in the food web. These individual populations are the keystone of the community's structure, and the integrity of the community and its unaltered persistence through time, that is, stability, are determined by their activities and abundances." Although Paine first described and defined the term keystone species, the definition mostly widely used to describe keystone species comes from Power et al. (1996), "we define a keystone species as one whose impact on its community or ecosystem is large, and disproportionately large relative to its abundance."

Even though the keystone species concept has been widely used and there is a generally accepted definition, there still exists ambiguity in the use of the term and difficulty in determining what constitutes a keystone species and what does not. Mills et al. (1993) states, "the lack of a clear operational definition hinders any political or legal implementation" and "the term keystone species is misleading because it indicates the existence of a species specific property of an organism, when in actuality the keystone role is particular to a defined environmental setting, the current species associations, and the responses of other species". These statements emphasize two important points: 1) applying the keystone species concept is difficult, and 2) the concept of keystone species is context dependent. With no definitive definition of what constitutes a keystone species and no specific method to determine if a species is a keystone or not, many biologists and conservationists have applied the term with only qualitative data (Power et al. 1996). Power et al. (1996) states that the field is littered with far too many untested anecdotal "keystone species." The keystone term has been applied, and possibly in some cases misapplied, to species that have been studied and determined to be both a keystone species and not a keystone species (Menge et al. 1994; see Power et al. 1996). Regardless of how keystone species are defined, the role a particular species plays in a community and landscape can be substantial. Impacts from keystone species are wide ranging, varying in how and the degree in which they impact an ecological community.

BEAVER AS A KEYSTONE SPECIES

Some species have been documented to have such an important role within their ecological community they can increase the production of terrestrial and aquatic systems for the benefit of a variety of species (Smith et al. 1991; Pollock et al. 2004). Beaver are one such species and have been documented impacting both the physical and biological environment in which they live (Naiman et al. 1988; Baker and Cade 1995; Simberloff 1998). Beaver are able to occupy a broad spectrum of ecoregions, occurring in North America from subarctic Alaska and Canada through the contiguous United States to Mexico and subtropical Florida. Before European settlement of North America beaver numbers are estimated to be 60-400 million (Seton 1929), while today their populations are estimated to be 6-12 million, 3-10% of their previous population (Naiman et al. 1988). As beaver populations recover, they are occupying much of their former range, although habitat loss restricts recolonization and reintroduction (Hall 1981; Larson and Gunson 1983). A severe decrease in beaver populations over the last couple hundred years has resulted in many of the physical and biological benefits from beaver being lost (see Baker and Hill 2003).

IMPACTS TO STREAM ECOSYSTEMS

Impacts from beaver can be both positive and negative, depending on site characteristics and history, current watershed processes and land management, and the longevity of dam-building activities. Even though the extent to which positive impacts from beaver has decreased, there are still many benefits gained from beaver activity (see Collen and Gibson 2001; Rosell et al. 2005). Most of the benefits from beaver come from the building of dams, which impacts: hydrology, geomorphology, water temperature, water chemistry, aquatic invertebrates, and plant and animal populations (mammals, birds, fish, reptiles, and amphibians) (Naiman 1986; Collen and Gibson 2001; Pollock et al. 2003; Rosell et al. 2005; Kemp et al. 2011). The primary instream habitat value of beaver dams is that they impound water to form ponds. These impoundments trap sediment (Butler and Malanson 1995), attenuate peak flows (Finnigan and Marshall 1997), help create diverse wetland environments (Naiman et al. 1988), and facilitate ground water recharge and retention (Bergstrom 1985; Parker 1986; Johnston and Naiman 1987; Finnigan and Marshall 1997). All these functions are the result of dams reducing stream velocities and spreading water over a large surface area. Beaver dams allow water to move through a system over longer time periods, increasing groundwater recharge and summer low flows and elevating groundwater levels (Bergstrom 1985; Parker 1986; Johnston and Naiman 1987; Finnigan and Marshall 1997), thus expanding the extent of riparian vegetation (Stabler 1985; Lowry 1993). During dry periods, Duncan (1984) reported that up to 30% of the water in an Oregon catchment could be held in beaver ponds. By increasing storage capacity, it has been suggested that large number of beaver dams will lead to greater flows during late summer (Parker 1986), which may result in continual flows in previously intermittent streams (Yeager and Hill 1954; Rutherford 1955). By reducing stream velocity, beaver dams dissipate stream energy (Halley 1995); creating depositional areas for sediment and organic material transported from upstream and reducing the erosion potential of a runoff event (Apple et al. 1984; Parker 1986). Naiman et al. (1988) found that relatively small dams could retain as much as 2,000 to 6,500 m^3 of sediment. These dams could be very important as sediment sinks in streams with high sediment loads. Channel incision is a widespread problem in semi-arid climates which degrades stream habitat and riparian areas (Pollock et al. 2011). In a study conducted on an incised stream channel in eastern Oregon, Pollock et al. (2007) found that aggradation rates behind beaver dams were significant enough, 0.075 m/year to 0.47 m/year, to increase riparian habitat by five times when compared to adjacent reaches where no dams existed. There results suggest that restoration strategies encouraging the recolonization of streams by beaver can rapidly expand riparian habitat along incised channels.

BEAVER INFLUENCES ON FISH HABITAT AND POPULATIONS

A meta-analysis of the literature and expert opinion on beaver impacts to fish and their habitat was recently conducted by Kemp et al. (2011). The most frequently cited benefits of beaver dams were increased habitat heterogeneity, rearing and overwintering habitat and flow refuge, and invertebrate production. Impeded fish movement because of dams, siltation of spawning habitat, and low oxygen levels in ponds were the most often cited negative impacts of beaver dams. Benefits (184) were cited more frequently than costs (119) and impacts were spatially and temporally variable and differed with species (Kemp et al. 2011). Even though there were 119 cited cases of non-beneficial impacts from beaver on fishes and fish habitat, 71.4% of these citations were speculative, while only 28.6% were based on quantitative analysis. In contrast, of the 184 cited positive impacts, only 48.9% were based on speculation while 51.1% were based on quantitative analysis. This results in only 34 cited cases supported by quantitative results of non-beneficial impacts from beaver, versus 94 cited cases supported by quantitative results for beneficial impacts from beaver. Also, of the 49 experts surveyed, Kemp et al. (2011) found that most considered beaver to have an overall positive impact on fish populations, through their influence on fish abundance and productivity.

Beaver facilitate the persistence of a varied riverine habitat mosaic (Hanson and Campbell 1963) through the creation of lentic (still water) patches within a corridor of lotic habitat (flowing water)

(Snodgrass and Meffe 1999), thereby increasing habitat heterogeneity across the landscape. The resulting habitat heterogeneity benefits a multitude of organisms, including fish. Beaver ponds create slow water pool habitat where such habitat is often rare. This allows fish that depend on pool habitat to move farther up a system, sometimes to reaches previously inhospitable. Many of the aforementioned benefits associated with beaver ponds and dams not only have implications to fish habitat but also to fish populations.

In a comparison of tidal shrub marsh and tidal herbaceous marsh vegetation types in the Skagit River Delta in Washington, Hood (2012) found that the difference of pool abundance between the two vegetation zones was due entirely from beaver dam pools. Out of the 65.5% tidal shrub marsh channel length attributed to pool habitat, 47.7% of the 65.5% was from beaver dams, while zero of the 16.4% tidal herbaceous marsh channel length was from beaver dams. Without beaver, the two vegetation zones would have had similar amounts of pool habitat, 17.8% and 16.4%, indicating that beaver activity provided almost three times more pool habitat available for fish use. Out of the seven fish species caught during this study, three-spine stickleback (*Gasterosteus* aculeatus) and juvenile Chinook salmon, listed as threatened under the Endangered Species Act, were the two fish species most frequently caught. Stickleback and Chinook had densities 2.2 and 3.3 (m^{-3}) and densities 5.1 and 8.0 (standardized by surface area) times higher in pools than in shallows. From a landscape perspective, pools increased low tide juvenile Chinook density 12.2 times higher per unit length compared to shallows. Higher fish densities in pool habitat, which were predominantly formed by beaver, suggest beaver dams provide valuable habitat and population implications for three-spine stickleback and juvenile Chinook salmon.

Beaver ponds provide important overwintering and rearing habitat for many stream fishes, and in streams lacking large deep pools the importance of these impoundments increases (Cunjak 1996). Overwintering and rearing habitat have implications to fish survival, fish production, and fish growth. For example, during winter, juvenile Coho salmon (*Oncorhynchus kisutch*) residing in side channels impounded by beaver dams utilize such habitats at a higher density, are consistently larger, and have a greater overwinter survival rate than juvenile Coho salmon that use side channels without beaver dams (Bustard and Narver 1975; Swales et al. 1986). Both Chisholm et al. (1987) and Cunjak (1996) observed that brook trout (*Salvelinus fontinalis*) had a strong tendency to move into the slow water habitat of beaver ponds to overwinter. Likewise, Jakober (1995, 1998) observed that, in Montana streams, bull trout (*Salvelinus confluentus*) and cutthroat trout (*Oncorhynchus clarkii*) aggregated in large numbers to overwinter in beaver ponds. Murphy et al. (1989) studied summer use of main stem and off-channel habitat in the Taku River, Alaska and found the highest densities of juvenile Coho in reaches upstream of beaver dams (0.59 per m^2) and virtually all the larger Coho were located in beaver ponds. These reaches accounted for only 0.7% of the total available habitat; yet, 34% of all the juvenile Coho were found there. They also found the average fork length, a surrogate for fish size, of juvenile Coho was larger for those found in beaver ponds versus those found in all other habitats.

There have been many studies to document the use of beaver ponds by a variety of fish species; however, the population effects on fish resulting from beaver dam removal have been less studied. Pollock et al. (2004) assessed current and historic distributions of beaver ponds and other Coho salmon rearing habitat in the Stillaguamish River, Washington and found that the greatest reduction in Coho salmon smolt production capacity originated from the extensive loss of beaver ponds. They estimated the current abundance of beaver ponds to be 0.49 km^2, 0.03% of the watershed, compared to a historical estimate of 9.3 km^2, 0.5% of the watershed. Historically, beaver ponds were estimated to have a smolt production potential of 7.6 million juveniles, accounting for 79% of the total smolt production potential in the watershed. Currently, beaver ponds have a total smolt production potential of only 537,000, a reduction from historic levels by 93%. Most, 92%, of the overall Coho smolt reduction resulted from the loss of beaver ponds.

CONCLUSION

The influence of beaver activity on fish production is of particular interest due to the endangered and threatened status of certain fish species (e.g., Chinook and Coho salmon, bull trout, steelhead) under the Endangered Species Act. Land management activities, including removal of beaver and their dams, have altered the quality and quantity of available habitat to many organisms. Dam building beaver influence the quality and quantity of different habitat types required for a variety of species, including fish. Fish populations have been shown to respond positively to habitat provided through beaver activity and also to use these habitats disproportionately to their availability (Murphy et al. 1989; Jakober et al. 1998; Lindstrom and Hubert 2004). Beaver have been documented to have such an important role within their ecological community that they increase the production of aquatic systems for the benefit of a variety of fish species (Pollock et al. 2003, 2007; Snodgrass and Meffe 1998; Schlosser and Kallemeyn 2000).

CORE COMPETENCY – QUANTITATIVE METHODS AND SPATIAL INFORMATION MGMT

LANDSCAPE AND HABITAT ATTRIBUTES INFLUENCING BEAVER DISTRIBUTION

INTRODUCTION

Beaver reintroductions infrequently occur without prior knowledge of present beaver locations and the location of suitable habitat for reintroduction. Due to this, many private and governmental organizations are developing habitat suitability models to prioritize locations for beaver reintroduction, such as the Grand Canyon Trust, Montana Department of Environmental Quality (MT DEQ), Utah Division of Wildlife Resources (UT DWR), and The Lands Council (www.grandcanyontrust.org; Carpenedo 2011; UT DWR 2010; Walker et al. 2010). These same organizations are limited by time, money, and personnel to collect field data and/or validate suitable locations for beaver reintroduction. Also, the geographic extent of many habitat suitability models may be limited to specific local areas or jurisdictional units.

Although there are many efforts being undertaken to quantify beaver abundance and spatial extent, information, and the exchange of that information, still lacks on beaver distributions across large geographic areas. The Pacfish / Infish Biological Opinion Effectiveness Monitoring Program (PIBO EM) is a large scale stream and riparian monitoring program that samples streams across the upper Columbia and upper Missouri River basins (Figures 3 and 4). The objective of PIBO EM is to determine whether riparian and aquatic systems are being degraded, maintained, or restored across the landscape and determine the direction and rate of change over time as a function of land management practices (e.g., timber harvest, road building, mining, cattle grazing). PIBO EM was not established to study beaver specifically but was designed to monitor the status and trend of stream ecosystems, which beaver have an impact on. There is much that can be opportunistically gleaned from data that wasn't intended to look at beaver distributions and habitat preferences. Given its large spatial extent, PIBO EM has the ability to partner with many organizations to provide much needed data and information on beaver distributions and habitat preferences. Also, the large number of streams sampled by PIBO EM occurs on many different Forest Service and Bureau of Land Management jurisdictional districts. For example, the Montana DEQ focused on the Big Hole River watershed in the Beaverhead-Deerlodge National Forest for its beaver habitat suitability model and knowledge of the PIBO EM dataset, which monitors 35 locations in the Big Hole River, could prove very valuable information. This information is not only valuable for knowledge of beaver distribution, but also for knowing where the sample locations are so that Montana DEQ staff could focus resources to other areas of the watershed. Collaboration and shared information amongst groups will allow for a more efficient use of limited funds and a more effective beaver reintroduction strategy.

METHODS

STUDY AREA AND SAMPLING DESIGN

Physical stream habitat and riparian vegetation data was collected at the reach scale (120-500m stream length; e.g., Frissell et al. 1986) within the upper Columbia River and upper Missouri River basins (Figures 2 and 3) using the approach implemented by the Pacfish/Infish Biological Opinion Effectiveness Monitoring Program (Kershner et al. 2004; Heitke et al. 2010; Leary and Ebertowski 2010). All sampling sites are located on federally managed land administered by the Bureau of Land Management (BLM) and U.S. Forest Service (USFS).

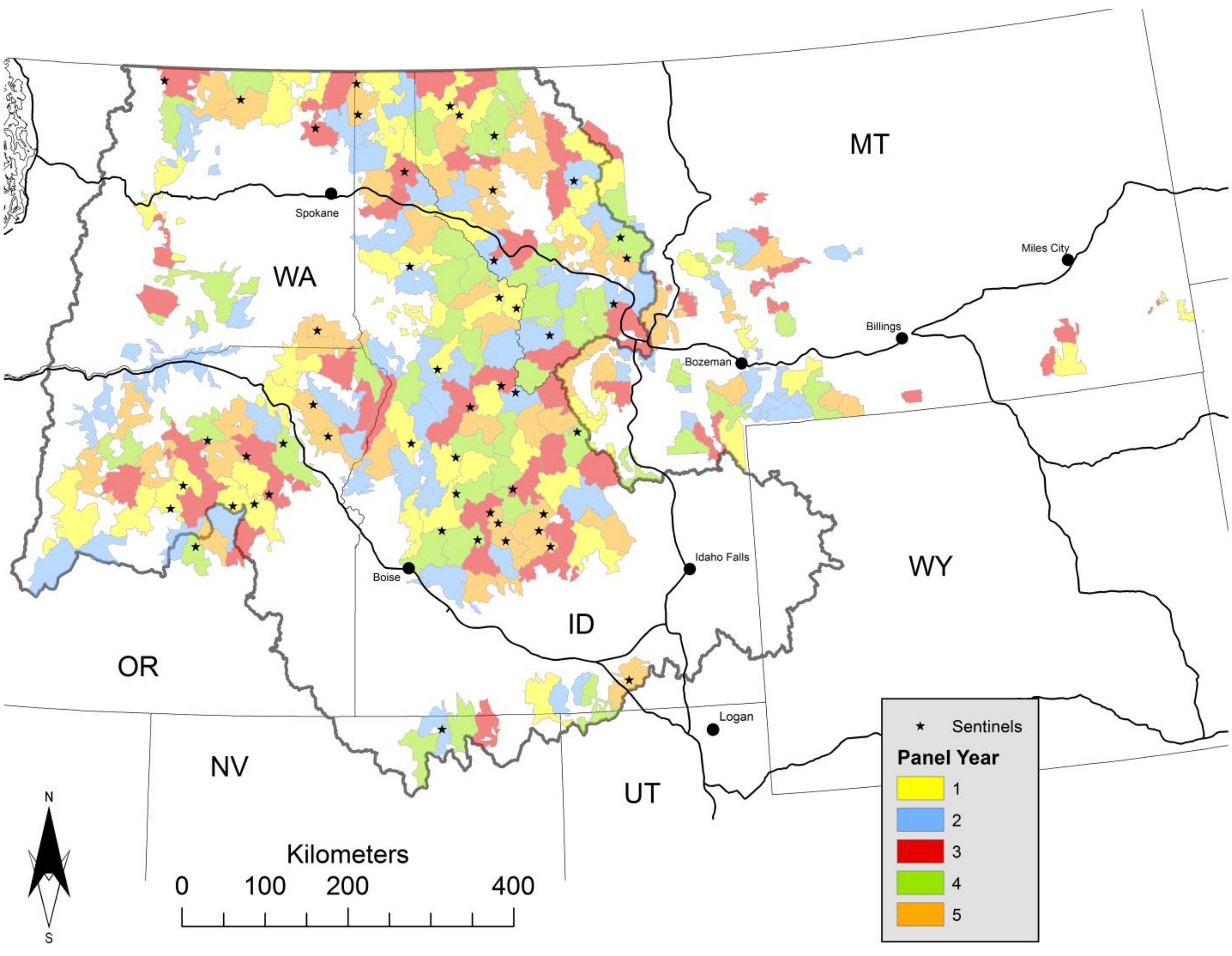

Figure 2 – Study area broken up into 220 groups, groups are separated into 5 panel years. ~44 groups are sampled each year.

Sampled watersheds were selected using a spatially balanced random sampling design (Figures 2 and 3; Table 1) (Stevens and Olsen 1999). BLM and USFS lands within the study area were divided up into 177 watersheds (also known as 'groups') in the upper Columbia and 43 watersheds in the upper Missouri river basins. Each group contains ~20 6th field hydrological unit code (HUC) watersheds. Approximately one third of all 6th field HUC watersheds, resulting in ~7 sampling locations per group, are sampled within the PIBO EM study area over a 5-year period; the same watersheds are then resampled over subsequent 5-year periods (Table 1) (Kershner et al. 2004). This design is represented as a rotating panel that is serially augmented and alternates over a given period (Table 1) (Urquhart et al. 1998). 50 watersheds are sampled yearly to evaluate temporal patterns, and are known as sentinel sites.

Table 1 – Rotating panel sampling design with the approximate number of watersheds sampled each year. The same 50 sentinel sites are sampled each year and the same 1500 integrator sites are sampled every 5 years (i.e., the same sites sampled in 2001 will be sampled in 2006, and so forth).

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Sentinel	50	50	50	50	50	50	50	50	50	50
Panel Year 1	300					300				
Panel Year 2		300					300			
Panel Year 3			300					300		
Panel Year 4				300					300	
Panel Year 5					300					300

Sampling locations occurred in both managed and reference, minimally managed, watersheds. Reference watersheds included both wilderness areas and watersheds where there was (1) no permitted livestock grazing during the last 30 years, (2) minimal timber harvest (<10%), (3) minimal road density (0.5 km/km²) at the watershed scale, (4) no roads within the proximate 1 km riparian buffer, and (5) no evidence of historic mining within riparian areas (Kershner et al. 2004). Watersheds where land management activities exceeded reference criteria were considered managed and were subject to a variety of activities: road building and maintenance, timber harvest, livestock grazing, mining, and motorized recreation.

Within each watershed, the lowest low-gradient site (gradient <3% based on ocular estimation) occurring on federally managed land that had at least 50% of federal ownership upstream was selected for sampling. Low-gradient sites were targeted because these areas are thought to be more sensitive to change under variable sediment, flow, and climate regimes (Montgomery and MacDonald 2002). Sites that were selected based on these criteria are known as integrator sites, and are intended to represent the cumulative effects within the watershed upstream from the integrator site. In some situations stream reaches with <3% gradient were not available; stream reaches were then selected up to 5% gradient.

In addition to integrator sites, PIBO EM also monitors Designated Monitoring Area’s (DMA’s). Designated Monitoring Area’s are an evaluation of whether or not the implementation of grazing practices over time is actually moving specific resource conditions toward desired conditions. These areas are monitored to determine if the end-of season grazing implementation standard has been achieved. DMA sites are not subject to the same site selection criteria discussed above for integrator sites; however, DMA sites are monitored using the same protocols as integrator sites (Heitke et al. 2010; Leary and Ebertowski 2010).

Each watershed that is grazed within an active allotment will have one or more designated monitoring areas where monitoring is to occur. DMA sample site locations are chosen by field unit personnel on individual Forest Service or BLM districts. Sample sites are chosen along stream sections that are representative of grazing within the watershed. Sample sites typically have vegetation that creates easy access to the stream by cattle (grasses, sedges, forbs, and minimal shrub cover). PIBO EM will only sample DMA sites where an integrator site is present within the watershed and will only sample one DMA per 6th field HUC. If more than one DMA exists within a 6th field HUC, PIBO EM will randomly select one DMA location to monitor.

In addition to integrator and DMA sites, PIBO EM also samples sites disregard of the original study design: contract and special project sites. Contract and special project sites are specific watersheds or locations that PIBO EM is hired to monitor using specific protocols (Heitke et al. 2010; Leary and Ebertowski 2010). These sites are usually not randomly selected and depending on the client, may or may not be selected using the integrator site selection criteria. Contract and special project sites are purposely selected for monitoring due to the specific needs and wants of the client.

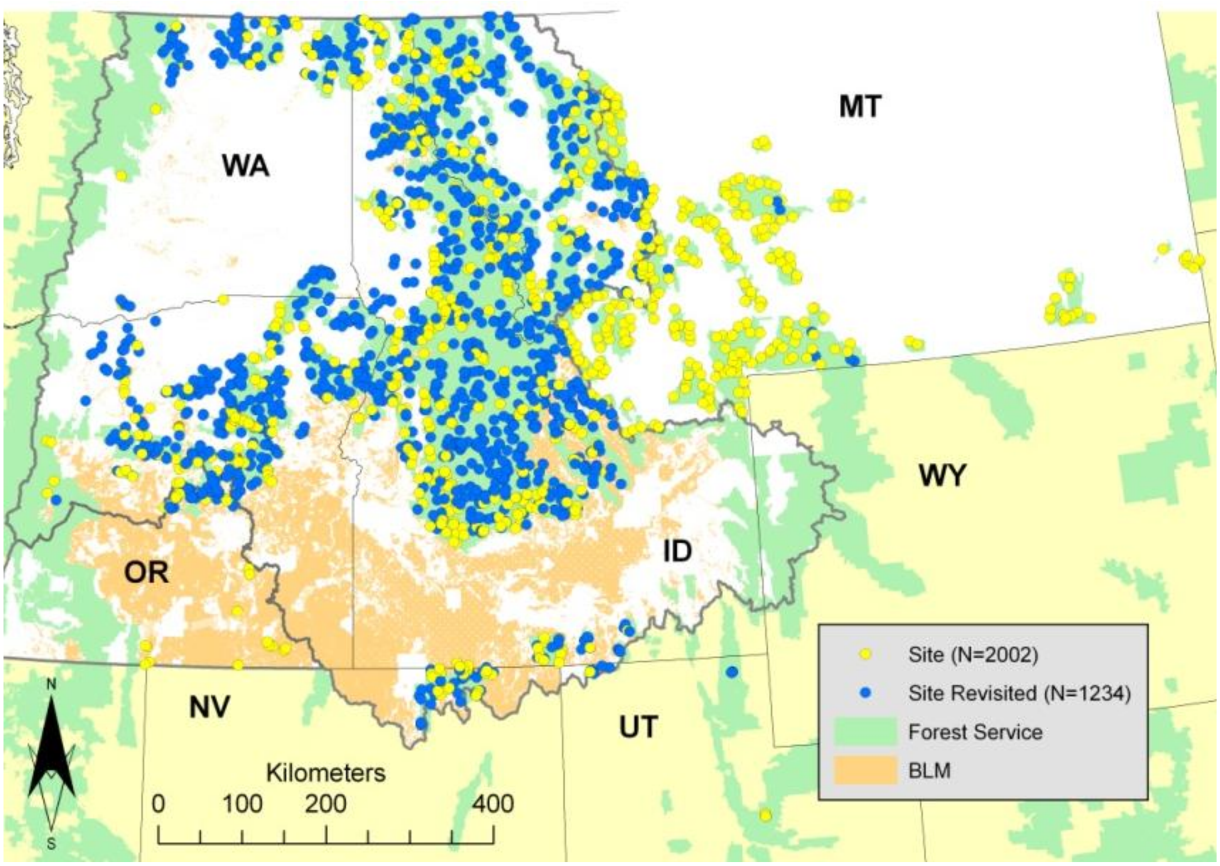

Figure 3 – PIBO EM sampling locations 2001-2010

FIELD SAMPLING METHODS AND DATA ACQUISITION

STREAM HABITAT DATA

Each year, sites are sampled during base flow conditions between June and September. Reach lengths were defined as 20 times the average bankfull width. Average bankfull width was determined by measuring four random locations upstream of the bottom of reach to categorize reaches into 2-m width categories. Within each evaluated site, stream physical habitat data was collected following methods according to Heitke et al. (2010). Although PIBO EM collects a wide variety of attributes, gradient, bankfull width, and sinuosity were specifically analyzed because these attributes are thought to be important, influencing beaver distribution and occupancy (Slough and Sadleir 1977). When sites were sampled more than once, average values were taken for each attribute.

Channel gradient was estimated in the field by measuring the change in elevation of the water surface between the bottom and top of reach using a site level and tripod and dividing this elevation change by reach length (Heitke et al. 2010). In riverine habitats, stream gradient is the major determinant of stream morphology and the most significant factor in determining the suitability of habitat for beavers (Slough and Sadleir 1977). For this reason, channel gradient was considered in this analysis.

Bankfull width was estimated in the field by measuring bankfull at each channel transect and then averaging these measurements over the whole reach (Heitke et al. 2010). Sinuosity is a measure of how much the stream channel meanders within the valley bottom. Sinuosity was estimated in the field by measuring the length of the stream channel along the thalweg (lowest points along the length of the river bed) and dividing that length by the straight-line distance between the bottom and top of the reach (Heitke et al. 2010).

VEGETATION DATA

Within each evaluated site, vegetation data was collected following methods according to Leary and Ebertowski (2010). Vegetation was sampled along the first line of perennial vegetation as one moves perpendicular and upland from the stream channel (hereafter called greenline; sensu Winwood 2000) and along riparian cross-sections. Vegetation was evaluated within Daubenmire (1959) quadrat frames (hereafter called plots; 50 cm x 20 cm). Greenline vegetation was evaluated in 20 to 26 equally spaced locations along the stream on both stream banks. Vegetation in the riparian area was evaluated at five evenly spaced channel transects for both sides of the bank. Evaluations were conducted 3, 6, and 9 meters upslope from the greenline and perpendicular to the stream channel. This sampling design resulted in 40 to 52 plots along the greenline and 30 riparian cross-section plots.

Within each sampled plot, PIBO EM technicians were asked to identify and determine the cover class of all species exceeding 5% cover. All plants which could not be identified in the field were collected and identified in an office by more experienced plant taxonomists. Cover of each species was visually estimated as falling into one of the follow cover classes; 5 to <15, 15 to <25, 25 to <38, 38 to < 50, 50 to < 75, 75 to <95, 95 to 100. For analysis purposes we used the mid points of these cover classes to describe cover in a plot. At each plot, cover for species were estimated for two heights, looking down from 1 m and looking up from 1 m. For each species, average cover was calculated by simply taking the average cover of all plots along the greenline and the cross-sections. As a result, if there was 100% ground cover and 100 overstory cover, total average cover at a site could be up to 200%. When sites were sampled more than once, average values were taken for each attribute.

LANDSCAPE ATTRIBUTES AND DATA

Publicly available geographic data sets and a geographical information system (GIS; Environmental Systems Research Institute (ESRI) ArcGIS 9.2) were used to derive landscape characteristics hypothesized to influence beaver distribution. Site locations were first identified in the field using geographic positioning system (GPS) coordinates and used to delineate catchment boundaries upstream of the bottom of reach using 10-m digital elevation models (DEMs) acquired from the U.S. Geological Survey (USGS) National Elevation Dataset (http://www.ned.usgs.gov). PIBO EM staff was responsible for delineation of catchment boundaries and deriving landscape characteristics for each site.

Catchment boundaries and a variety of open source data sets were used to calculate: catchment area (km/km^2), stream drainage density (km/km^2), road density (km/km^2), average precipitation (m), and average temperature (°C). Stream drainage density was calculated using stream layers from the 1:24,000-scale U.S. Geological Survey (USGS) National Hydrography Dataset (USGS 2000). Road density was calculated using data from the USFS Geodata Clearinghouse (1:24,000 scale; USFS 1995). Precipitation and temperature data came from PRISM Climate Group (http://www.prism.oregonstate.edu/). Average precipitation was calculated as the weighted average (by area) of all precipitation grids (16 km^2) that were intercepted by each individual catchment. For each grid, 30-year average precipitation values were used (1971– 2000; PRISM 2004). Average temperature was calculated as the weighted average (by area) of all temperature grids (16 km^2) that were intercepted by each individual catchment. For each grid, yearly average of average monthly air temperature values were used (2001-2008; PRISM 2004).

Forested habitat (i.e., all tree-dominated vegetation) was quantified at the reach scale (section of stream 10 m wide and extending 300 m upstream from the bottom of the site) for each site using land cover data from the Landscape, Fire, and Resource Management Planning Tools Project (LANDFIRE 2008). Percent forested habitat has been used in habitat suitability index models as a measure of suitable habitat for beaver (Allen 1983). Elevation was derived using site GPS coordinates and 10-m DEMs from the USGS National Elevation Dataset.

BEAVER DETECTION

PIBO EM has been monitoring streams and riparian areas since 2001 within the upper Columbia River basin and since 2006 within the upper Missouri River basin. The extent to which beaver activity has been documented has evolved through time and has undergone significant improvements. Beaver activity within a reach was less emphasized from 2001 to 2005, where reaches were not supposed to be impacted by beaver during the first visit, compared to 2006 to 2010. From 2001 to 2005, field crews were not provided specific instructions to document beaver presence, impacts, or activity. The only source of confirming beaver activity within a reach during this time was from notes proactively made by field crews at time of sampling, photos showing beaver ponds and/or dams, and from hand-drawn reach maps indicating the presence of beaver. This was inconsistently done and no specific method existed for documenting beaver presence at a reach.

Another problem with beaver detection was that beaver impacted areas were avoided during site establishment; however, sites that became impacted by beaver were sampled during subsequent visits. With no protocol in place or training provided for how to sample in beaver impacted areas, PIBO EM did not address sampling in beaver impacted reaches until 2006, the second rotation of sampling each panel year. Since 2006, the first year sites were re-sampled in the upper Columbia River basin, methods have been developed and specific instructions were provided to better document beaver presence and impact within sampled reaches (Heitke et al. 2010).

Sites established in 2001 have been visited twice (except for the 50 sites sampled annually) and sites established in 2006 have been visited once (Table 1). Since sites within the upper Missouri River basin have only been sampled once and beaver impacted areas were avoided during site establishment, beaver detection is limited (Figure 4).

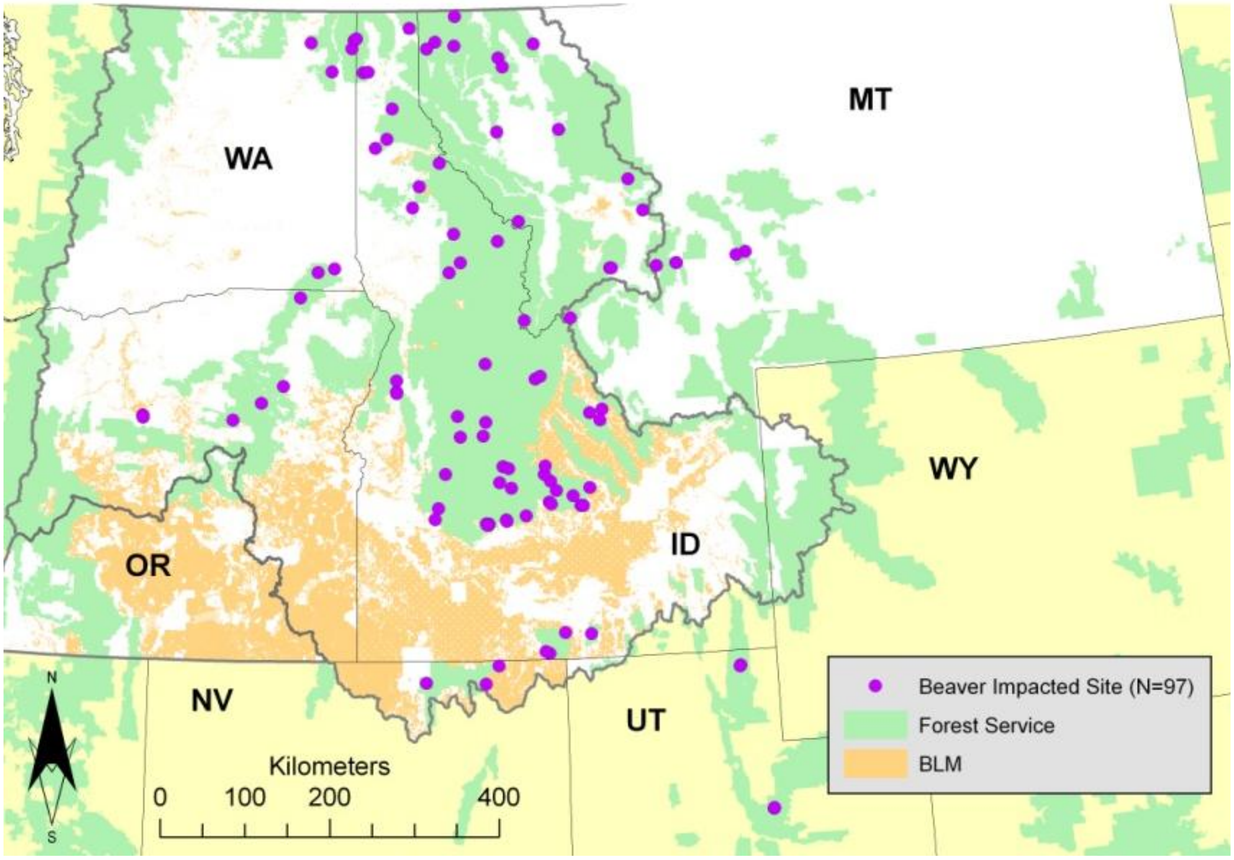

Figure 4 – PIBO EM sampling locations from 2001-2010 with beaver activity

RESULTS

From 2001 to 2010, PIBO EM has sampled 2,002 sites within the upper Columbia and upper Missouri River basins. 62% of these sites have been sampled more than once, for a total count of 3,681 reaches sampled. Beaver presence has been documented in 97 of 2,002 sites and 125 of 3,681 reaches, resulting in 4.8% of all sites and 3.4% of all reaches having been occupied by beaver at one time. Of the 50 sites that are sampled annually, 10 sites (20%) have had beaver activity at least once.

Beavers will live in close proximity to man if all habitat requirements are met (Rue 1964). However, railways, roads, and land clearing often are adjacent to waterways and may be major limiting factors affecting beaver habitat suitability (Slough and Sadleir 1977). Study sites were not subjected to close proximity to humans since all sites occurred on U.S. Forest Service and BLM lands; however, many management activities have occurred on public lands, possibly influencing beaver distribution (Tables 2-4). To look at the impact of roads on beaver distribution, distance between sampling locations (sites) and the nearest road were calculated using the near tool in ArcGIS (Table 2). Using a t-test to compare distances between sites with and without beaver activity resulted in a p-value of <0.0001. Not only was the presence of roads thought to possibly influence beaver distribution but also the density of roads.

Using a t-test to compare catchment road density between sites with beaver activity and sites without beaver activity resulted in a p-value of 0.158.

Table 3 shows the breakdown of beaver and non-beaver sites into three different management categories: managed and grazed, managed and not grazed, and reference (no management). Beaver sites that were not grazed made up 43% of the beaver sites and 8.3% of all non-grazed sites. Beaver sites that were grazed made up 56% of the beaver sites and 3.6% of all grazed sites. Performing a chi-square analysis to compare the presence of grazing at sites with and without beaver produces a p-value of <0.0001.

Landscape, site, and vegetation attributes thought to be important, influencing beaver distribution are presented in Tables 4-6. Attributes that were found to be significant at a p-value of 0.10 using a t-test comparing beaver and all other sites include: catchment area (km^2), channel gradient, sinuosity, percent Salix spp. cover, percent forested, and percent herbaceous cover. Three of five (60%) attributes found to be significant were vegetation related, while vegetation related attributes only comprised four out of thirteen attributes (30%).

Table 2 – Distance from PIBO EM sampling location to nearest road (meters).

Statistic	Beaver Sites	All Sites
Minimum	5.2	0.1
Maximum	16,679	108,473
Mean	763	1,967
Median	94	169
Standard Deviation	2,034	6,627

Table 3 – The number of sites are displayed for each type of land management; comparing beaver sites versus all other sites.

Site Management	Beaver Sites	All Sites
Managed and Grazed	54 (56%)	1428 (75%)
Managed and Not Grazed	36 (37%)	204 (11%)
Reference	7 (7%)	273 (14%)
	N=97 (100%)	N=1905 (100%)

Table 4 – Landscape attributes that were considered important to beaver distribution were calculated within PIBO EM catchments. Attributes that were found to be significant at a p-value of alpha=0.10 with a t-test comparing a beaver and all sites are marked with two asterisks (**).

Landscape Attribute	Beaver Sites			All Sites		
	Min	Max	Median	Min	Max	Median
Catchment Area (km^2)**	3.76	326	40.79	0.10	1423	27.50
Average Temperature (°C)	-0.12	8.06	3.67	-2.50	10.99	3.94
Average Precipitation (m)	0.48	1.51	0.84	0.27	1.98	0.80
Stream Density (km/km^2)	0.77	2.34	1.26	0.21	4.18	1.29
Catchment Road Density (km/km^2)	0	4.39	0.71	0	7.18	0.81

Table 5– Site attributes that were considered important to beaver distribution were measured at PIBO EM sites. Attributes that were found to be significant at a p-value of alpha=0.10 with a t-test comparing beaver and all sites are marked with two asterisks (**).

Site Attribute	Beaver Sites			All Sites		
	Min	Max	Median	Min	Max	Median
Elevation (m)	521	2657	1649	115	2715	1473
Channel Gradient (%)**	0.005	8.17	0.88	0.005	25.82	1.68
Bankfull Width (m)	1.57	24.63	5.49	0.41	25.05	5.05
Sinuosity (reach length/straight length)**	1	2.44	1.35	1	5.66	1.29

Table 6 – Vegetation attributes that were considered important to beaver distribution were measured at PIBO EM sites. Attributes that were found to be significant at a p-value of alpha=0.10 with a t-test comparing a beaver and all sites are marked with two asterisks (**).

Vegetation Attribute	Beaver Sites			All Sites		
	Min	Max	Median	Min	Max	Median
% Woody Cover	4.39	96.06	41.47	0.14	123.96	43.15
% Salix spp. Cover**	0.30	49.65	13.89	0.12	63.83	5.60
% Forested (GIS)**	0	97.40	43.50	0	100	81.16
% Herbaceous Cover**	10.84	83.95	36.40	1.15	86.37	33.41

DISCUSSION

Historically, beaver were present in streams, ponds, and the margins of large lakes throughout North America, except for peninsula Florida, the Arctic tundra, and the southwestern deserts (Jenkins and Busher 1979). With such a wide geographic distribution beaver could be considered a generalist; however, suitable habitat for beavers must contain all of the following: (1) stable aquatic habitat providing adequate water; (2) channel gradient of less than 15%; and, (3) quality food species present in sufficient quantity (Williams 1965; Fryxell 2001). Many others have echoed these same habitat requirements for beaver (Allen 1983; Slough and Sadleir 1977).

The type of food species and the quantity available play a critical role in determining beaver distribution (Slough and Sadleir 1977). As important as this may be, it has also been documented that beavers will occupy locations without preferred food sources (Beier and Barrett 1987). Jenkins (1975) reported that although several tree species (aspen (*Populus tremuloides*), willow, cottonwood (*P. balsamifera*), and alder (*Alnus spp.*) have often been reported to be highly preferred foods, beavers can inhabit, and often thrive in, areas where these tree species are uncommon or absent. Again, data collected by PIBO EM highlights that beaver will and do occupy a wide range of sites with differing vegetation characteristics but do select for certain attributes (Table 6). The amount of forest cover by trees, the percent of *Salix spp.* present, and the amount of herbaceous vegetation present were all significant at a p-value of 0.10 with a t-test comparing sites with beaver activity against all sites. It is assumed that a tree and/or shrub canopy closure between 40 and 60% is an indication of optimum food availability and closures exceeding 60% are assumed to be less suitable due to the decreased accessibility of food (Allen 1983). Median percent forest cover is almost half in sites occupied by beaver, 43.50 versus 81.16 (Table 6). The types of food species present may be less important in determining habitat quality for beavers than physiographic and hydrologic factors affecting the site (Jenkins 1981).

Allen (1983) reported that stream channel gradients of 6% or less have optimum value as beaver habitat. Retzer et al. (1956) reported that 68% of the beaver colonies recorded in Colorado were in valleys with a stream gradient of less than 6%, 28% were associated with stream gradients 7 to 12%, and only 4% were located along streams with gradients of 13 to 14%. No beaver colonies were recorded in streams with a gradient of 15% or more. Even though PIBO EM selects sampling locations with gradients under 5%, beaver are selecting for stream reaches with lower channel gradients (Table 5). A t-test comparing stream gradient at sites that have been occupied by beaver to all sites gives a p-value of <0.001, indicating that beaver are seeking out lower gradient stream sections. This data confirms past evidence that beaver select for lower gradient sections of stream (Beier and Barrett 1987; Suzuki and McComb 1998).

Water provides cover for the feeding and reproductive activities of beaver and a permanent and relatively stable source of water is mandatory for suitable beaver habitat (Allen 1983). All except for one PIBO EM site that has had evidence of beaver activity has perennial flow. One site went dry between visits, stream was flowing in 2003 and almost completely dry in 2008, and there is picture evidence that shows beaver building earthen dams, possibly trying to retain water.

Sites with beaver activity were found closer to roads when compared to all other sites (Table 2). Many of the sites PIBO EM samples that are located further distances from roads are in wilderness areas, usually at higher elevations, commonly forested, and typically are of larger stream size. Although beaver will occupy sites with these types of characteristics (Tables 5 and 6), based on previous results from the literature, beaver do not select for these habitat characteristics (see Beck et al. 2010) Pressure from beaver trappers may have had an influence on pushing beaver into more undesirable habitats, influencing broader distributions. Also, one would assume that there is more trapping pressure closer to roads, possibly pushing beaver away from roadways and into areas less desirable for trapping, although the data in Table 2 does not support this.

Roads are one type of management that influences beaver distributions. Cattle/sheep grazing and the interaction between beaver and cattle/sheep competing for similar resources also effect beaver distributions. Table 3 shows the breakdown of beaver and non-beaver sites into three different management categories: managed and grazed, managed and not grazed, and reference (no management). A chi-square analysis comparing the presence of grazing at sites with and without beaver produces a p-value of <0.0001. Although most of the sites PIBO EM samples are grazed (75%), beaver are selecting for sites that are not grazed: 44% of beaver sites are not grazed while only 25% of all sites are not grazed. Cattle spend much of their time grazing in riparian areas, creating competition for woody species desirable by both beaver and cattle. Over-grazing limit available resources for beaver, possibly pushing them to areas void of grazing pressure. Millions of acres of public land are open to grazing, limiting food supplies and dam construction materials, but more importantly, possibly limiting beaver populations and distributions. Successful beaver reintroductions and management plans not only have to consider the available habitat but the influences upon that habitat and how land management activities, such as grazing, are altering the habitat available to beaver. Competition between beaver and cattle/sheep grazing can also be viewed from the standpoint of those who graze cattle and sheep. Direct removal of woody browse for dam building materials and as a food source limit forage available for cattle and/or sheep. In addition, flooding from dam building creates anaerobic conditions killing off woody browse and possibly flooding entire riparian areas changing entire plant communities.

CONCLUSION

From 2001 through 2010 PIBO EM has found that 5% of all sites have had some form of beaver activity. This is a promising number given the small extent to which PIBO EM is able to determine beaver presence/absence: only sampling reaches 200-500 m in length, not all sites have been revisited, and sites with beaver activity were avoided during site establishment. Another optimistic figure is that 10% of sites that have been visited annually have shown some indication of beaver activity. As PIBO EM continues to resample streams, more data and information will be obtained, which will hopefully shed more light on what habitat requirements beaver are selecting for. Additionally, PIBO EM will be able to provide valuable information to other organizations on what these habitat requirements may be and the current distribution of these animals. As more information is gathered, an assessment of how long beavers remain active in a given area could also help determine habitat preferences.

Preliminary data from PIBO EM suggests that as beaver populations make a comeback they will occupy a diverse range of habitats (see Appendix A for a selection of pictures illustrating the diversity of habitats beaver occupy). Much of the data from Tables 2-6 demonstrate that beaver occupy a wide range of landscape characteristics and site habitats, but particular attributes are more important than others in determining where beaver are present. The diversity of habitats should be of no surprise since beaver were historically present across most of the country in high numbers. The overlap of so many landscape, site, and vegetation attributes between sites with beaver activity and all sites, and the fact that the vast majority of PIBO EM sites are without beaver, indicates that many areas may already be suitable for beaver occupation but population levels are too low. Many groups and organizations are putting money, effort, and time into coming up with habitat criteria and habitat suitability indexes for beaver reintroduction but is that the right question to be asking? Is habitat what is lacking or most important? Maybe the solution for increasing beaver population levels lies more in beaver protection than suitable habitat. More and more beaver reintroductions and restoration projects using beaver are taking place, but until beaver are considered an essential part of the ecosystem and warrant the protection they deserve, money, time, and effort could be wasted. The habitat may be there, but all we really need is more beaver.

CORE COMPETENCY – HUMAN DIMENSIONS

CAN BEAVERS BENEFIT HUMANS? WATER STORAGE AND SUSTAINABILITY

Historically, beaver were found in greater numbers and distribution than present and influenced the structure and function of streams, riparian areas, and fish and wildlife populations (Baker and Hill 2003). The ecosystem role and landscape influences of beaver are becoming increasingly understood and accepted. As beaver awareness continues to grow, beaver reintroduction is becoming a popular restoration tool for land managers. Beaver have been used to restore lost or degraded ecological functions (Pollock et al. 2007; Pollock et al. 2011), increase fish and wildlife habitat (Pollock et al. 2004; Amish 2006), and aid in wetland development (Naiman et al. 1988). Currently, beaver reintroduction is being explored by many groups and organizations across the arid western United States as a method of contributing to water storage, increasing late season flows when water demand is the highest (Walker et al. 2010, Bird et al. 2011). For example, The Lands Council is actively pursuing the assistance of beaver to store early spring runoff and increase year round availability of water to residents in eastern Washington. Using The Lands Council as a case study for this section, I will look at water storage through the use of beavers from a sustainability viewpoint, and consider how these animals may be able to assist eastern Washington residents in storing three million acre feet of water.

Water is used in many aspects of human life and life itself depends on water; therefore, it is an essential resource needed by human beings. Water is needed by a diverse group of users including uses for agriculture, ranching, recreation, fish and wildlife, and human consumption. With a diverse group of users comes a diversity of values and different thoughts and ideas on water regulation and use. Although this resource is essential to human beings, water has continually been misused and mistreated.

Water availability and storage are two very important issues currently facing many communities and cities across the United States. While this is not a new problem, people have been dealing with trying to store water for later use for thousands of years (Fahlbusch 2009), today, we have some additional concerns that increase the challenges associated with water storage; global warming and reduced quantities of water (Moore et al. 1997; Barnett et al. 2005; Schindler and Donahue 2006). The quantity of water is becoming more of a concern as consumption increases, especially across the arid western United States where water availability is decreasing (Regonda et al. 2005). Global warming also plays a role in the amount of water available, due to warmer temperatures, earlier springs, and drier summers, all increasing water scarcity (Westerling 2006). This has raised the question, "Will there be enough water to meet the increasing demand?"

One of the main concerns regarding water availability and storage is that there is plenty of water available during the winter and spring but the inability of our streams to store spring runoff has resulted in reduced flow when peak water demand occurs in summer and fall. Thus the problem we have is when water demand is at its highest; there is the least amount of it. Seasonal changes in water availability and water demand, depletion of underground aquifers, and the lowering of water tables has resulted in the engineering and building of reservoirs and dams for water storage. Dams have been around for thousands of years (Fahlbusch 2009) but within the last hundred years dams have become bigger, storing more water, but also much more expensive both financially and environmentally. The availability and storage of water is a good thing, but there are many disadvantages with changing the storage method from recharging aquifers by keeping water on the landscape in a diversity of places (i.e., wetlands), to storing water in one concentrated place behind a concrete wall. The negative effects from man-made dams and reservoirs are outside the scope of this paper; however, both the literature and social stigma/attitude/media suggests there are many opponents and much animosity towards dams and reservoirs.

Climate change and increased demands for water in the Columbia River basin are urgent issues (Casola et al., 2006). Eastern Washington faces increasing water demands and a relatively fixed supply of water. In 2006, Washington State Legislature directed the Department of Ecology (DOE) to "aggressively pursue development of water supplies to benefit both in-stream and out-of-stream uses" by enacting House Bill 2860, commonly referred to as the "Columbia River Basin Water Management Program". The objective of this program is to provide an additional 3 million acre-feet of water storage to benefit people, farms, and fish during low flow periods of the year. Initially, the DOE looked at building new reservoirs and dams on tributaries of the Columbia River. The many problems associated with water storage through man-made reservoirs and dams have spurred new innovative ideas for water storage. As a result of public perception towards dams, the DOE also partially funded The Lands Council in Spokane, Washington to research beaver activity and dam building as a viable water storage option. The purpose of The Lands Council's research was to: (1) understand the potential of using beaver dams to store water and increase late-season flow in the upper Columbia River basin; and, (2) to identify suitable habitat for beaver throughout 12 eastern Washington counties (those east of the Cascade divide).

Prior to the colonization of North America by European settlers, it is estimated that beaver numbered close to half a billion, with a range from the Arctic tundra south to the deserts of Mexico (Allen 1983). Recent population estimates range from 6-12 million (Naiman et al. 1986), while in eastern Washington biologists estimate ~50,000 beaver, a much lower number than historic levels of ~500,000. With so much of the landscape historically occupied by beaver, The Lands Council believes that the reintroduction of beaver will play a vital role in not only meeting the requirements of House Bill 2860, but also in preventing the creation of new dams and reservoirs.

Beaver function as ecosystem engineers, profoundly impacting stream hydrology, increasing water storage, and raising water tables (Naiman 1988; Lowry and Beschta 1994; Gurnell 1998; Westbrook et al. 2006). Evidence from the literature also suggests that beaver dams and groundwater reserves act as a buffer to stream systems, holding back snowmelt and rain runoff and releasing it over time, increasing late season stream flows (Parker 1986; Gurnell 1998; Collen and Gibson 2001). Even though evidence exists for the benefits obtained from beaver ponds, eastern Washington and The Lands Council still were uncertain of how much water could be stored by beaver and if it would be able to meet the requirements of House Bill 2860 with increasing the beaver population. They also needed to know how much suitable habitat was available for beaver to repopulate. Based on their research, The Lands Council concluded that 2.2 to 4.1 million acre feet of water could be stored on the 9,800 miles of stream that were found to be suitable for beaver occupation (Walker et al. 2010). They also concluded that ~220,000 beaver would be needed to meet their water storage estimates (Walker et al. 2010). Based on these conclusions, eastern Washington can support a larger beaver population, increasing water storage and late season flow, making beaver restoration a viable and relatively inexpensive way of fulfilling House Bill 2860, all while preventing the creation of new man-made dams and reservoirs. Maintaining and relocating beavers into their historic habitat provides a natural mechanism for improving the environmental conditions in Washington's riparian ecosystems without having to resort to governmental regulation or expensive publicly funded engineering projects.

Looking at this topic in a sustainability framework, one must consider the four principles of sustainability posed in Dr. Joseph Tainter's 2008 keynote address, "Environment and Development for Third World Countries," at the VIth International Media Forum on the Protection of Nature in Viterbo, Italy: (1) sustainability is a human matter, not exclusively an environmental one; (2) a society achieves sustainability through success in solving problems; (3) energy and natural resources are the bases of sustainability; and (4) sustainability must be objectively measured. These four principles apply to the goals and objectives of The Lands Council's plan to reintroduce beaver as a means to store water for year round use. Regardless of the environmental benefits, The Lands Council approaches the problem of water availability and storage from an issue of sustainability for people, not, "protect the environment and people will be fine", type of attitude. The issue that faces eastern Washington is an issue that will affect everyone and an issue that everyone should be concerned about. Approaching water related problems from the standpoint of how a problem directly impacts individuals should inspire creative and innovative solutions. And, this is exactly what has happened, beaver activity as a means to increase water storage: problem solving to help achieve sustainability, using natural resources as the basis. In addition, this is not a feel good story about protecting beaver and water will increase. Rather the study and research has specific goals it is trying to achieve, 3 million acre feet of water, with specific numerical results showing how the goal can be achieved while objectively measuring sustainability.

The word 'sustainable' and 'sustainability' are becoming increasingly popular and more frequently used, all while creating confusion as to what exactly 'sustainable' or 'sustainability' actually mean or represent. In many situations where sustainability is referred to, it is unclear as to what exactly is supposed to be sustained. Tainter (2008) argues that any analysis of sustainability should begin with four questions: (1) what is being sustained?; (2) whom is it being sustained for?; (3) sustain it for how long?; and, (4) sustain it at what cost? These are difficult questions to ask, even more difficult to answer, and therefore rarely posed when talking about sustainability. Without these questions it is hard to clearly and effectively communicate what someone is talking about when referring to sustainability. With them, sustainability goals can be put into place with details on what specifically is being accomplished. Sustainability goals that address the four questions posed by Tainter (2008) create less (possibly no) vagueness and demonstrate what exactly is being sustained and at what cost. However, answering the four questions does not avoid the problem of people/society coming to a consensus on answers to the four questions. Answering the four questions will depend on what people and society value. Different groups of people value different things, creating controversy and disagreement when trying to establish: what should be sustained, whom should it be sustained for, how long should it be sustained for, and at what cost do we sustain it.

For this sustainability analysis, regarding the case study of eastern Washington and The Lands Council, it seems clear as to how they have addressed the four questions of sustainability:

1. Sustain what? The Lands Council has a very specific goal of trying to sustain 3 million acre feet of water storage through use of beaver activity, avoiding having to build more artificial dams and reservoirs.
2. Sustain water for whom? Mainly, water consuming citizens, although there will be many other ecosystem and fish and wildlife benefits.
3. Sustain water for how long? People will always need a source of clean, freshwater. Without water many industries would fail, sanitation and health would decrease, and life itself would become very difficult. Ideally, water will be sustained for as long as possible. But in order to indefinitely sustain water for year round availability, many other problems will need to be addressed or water many not be sustained at all. Some of these problems include population growth, development, water and energy consumption, as well as destruction of wetlands and beaver habitat.
4. Sustain water at what cost? Using beaver as a tool to increase water storage will have many associated costs affecting many people. The possible desire for more beaver could impact current laws and economies of beaver trapping. An increase in the beaver population will most likely result in flooding on private land, including valuable agricultural and ranching property, creating economic losses for these groups. These groups may not respond well to increasing beaver numbers but they will also want water throughout the year.

The Lands Council is able to describe their sustainability goal within the framework of the four questions of sustainability posed by Tainter (2008), but that does not mean the rest of eastern Washington has the same solutions to the water availability and storage problem or the same sustainability goals. To date, it is yet to be seen whether The Lands Council will succeed in using beaver as a way to store water for year round availability and use. Society values and public perception will be the two biggest obstacles facing The Lands Council in meeting their sustainability goals. Beaver are still considered a pest by many people; however this attitude is rapidly changing with the acknowledgment that the negative impacts are outweighed by the positive impacts. Conflict will not be avoided but can be anticipated and planned for. A key to the success of The Lands Council lies in public outreach and education. In recent years, many groups and organizations have been spending time, money, and effort on increasing education and awareness on the role beavers play in the landscape and how to live with them (Tippie and O'Brien 2010). The Lands Council is trying to achieve sustainability through problem solving, public outreach and education, all while considering temporal and spatial scales and the needs of both humans and the environment.

INTRODUCTION

In economics, the term "value" implies a good or service has worth because it is scarce or has utility to people. As with any economic good or service, the total economic value associated with a particular good or service is made up of use values and non-use values (Figure 5). These same values of "use and non-use" can be applied to wetlands and river restoration. Use values include direct and indirect values, and for river restoration this includes a wide variety of ecosystem services such as fish and wildlife production, water quality, flood control, and recreation. River restoration also provides widespread non-use benefits to people who obtain satisfaction from knowing that native species exist in their natural habitat (i.e., existence value) or from knowing that restoration today provides native species and their natural habitats to future generations (i.e., a bequest value).

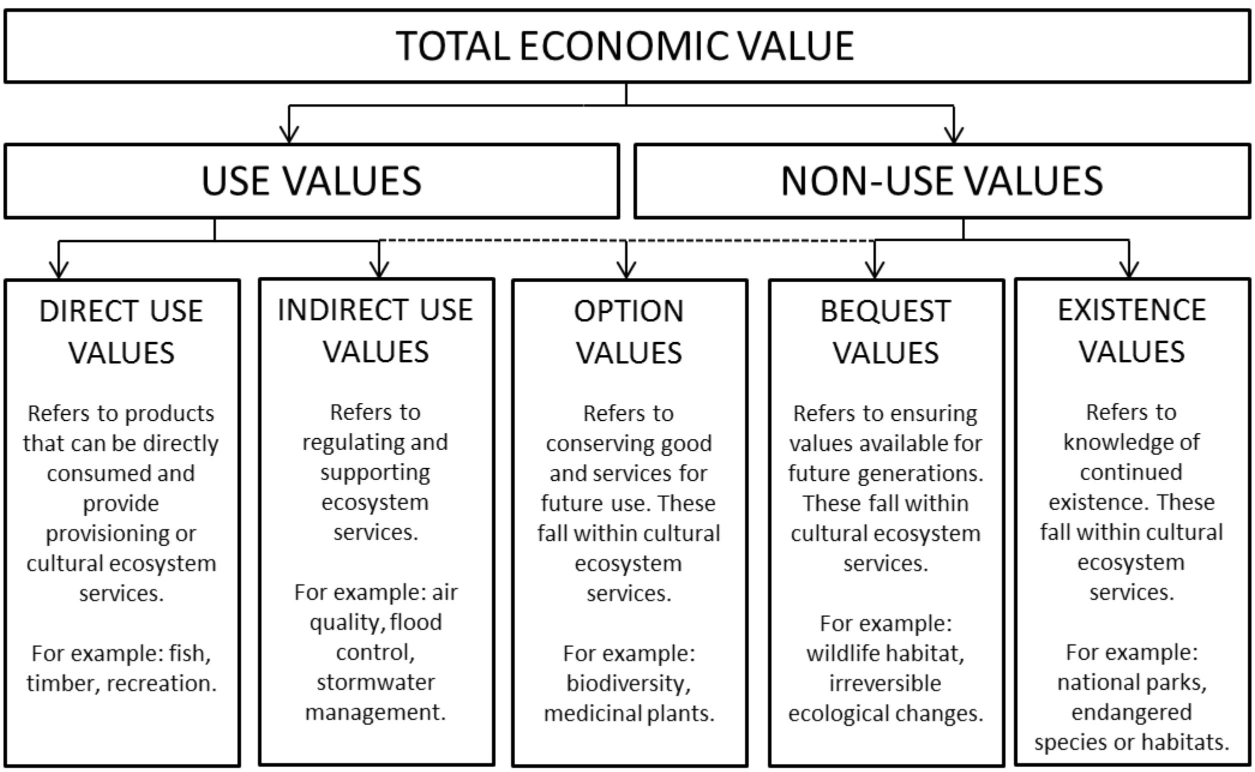

Figure 5 – Framework for visualizing the full range of social values generated from a good or service is the concept of total economic value. (Figure adapted from Robbins and Daniels 2012)

Previous studies have shown that existence values can make up at least half the benefits of improving water resources (Fisher and Raucher 1984; Sanders et al. 1990). As such, it is important to include non-use benefits when calculating the benefits of wetland restoration. Unfortunately, unlike most use values, non-use values are public goods and their values are not fully reflected, or do not exist in markets. However, economists have developed nonmarket methods for determining non-use values:

revealed preference methods and stated preference methods. Revealed preference methods observe what people do: where people go and how often (travel cost method); what goods people buy, how much they pay, and how much the goods differ (hedonic pricing method). Stated preference methods rely on asking people questions (e.g., the use of surveys) to determine a willingness to pay for certain environmental improvements.

Even though it can be difficult to describe and quantify the total economic value of restoration, since many ecosystem benefits and services are not bought and sold in existing markets it is still worthwhile to make such an effort. With an average of over $1 billion spent annually in the United States from 1990-2003 on river restoration (Bernhardt et al. 2005) having information about the use and non-use values of a restoration project can aid decision makers in selecting among those restoration projects which provide the greatest benefits to society as a whole. If society is willing to make such large expenditures on restoration efforts, then the ecosystem benefits and services improved through such efforts clearly have value. In addition, the listing of many aquatic species, including many fish species, under the Endangered Species Act is one reason why both public and private agencies are working to improve and restore riverine habitats. As restoration projects expand in frequency and scale, some prioritization becomes inevitable and integrating economics into planning and implementation can improve a project’s effectiveness by allocating limited budgets and resources where they will have the greatest results.

ECONOMIC INCENTIVES TO USE BEAVER FOR STREAM RESTORATION

INTRODUCTION

Although wetlands were historically viewed as a waste of valuable land (Mitsch and Gosselink 1986), today the economic value and recognition of the ecological services provided by wetlands is widespread (Turner 1991). Many attempts and evaluations have been made on assigning economic values to wetlands. In the context of stream restoration through beaver activity, attributing economic benefits to the services beaver provide yields a quantitative measure on impacts from beaver. While relevant literature does not directly address the economic values of beaver activities, there exists a substantial literature on the economic value of the natural capital affected by beavers (Turner et al. 2000; Woodward and Wui 2001; Brander 2006; Ghermandi et al. 2010). Bridging the gap between literature addressing beaver impacts and literature addressing the economic value of wetlands and natural resource capital provides a clearer picture to the overall benefits of using beaver for stream restoration. The benefits of dam building beaver are wide ranging, involving many topics and disciplines. All topics are not covered here, but rather a sampling of topics is discussed to demonstrate the wide range of economic benefits beaver have.

WETLAND CREATION

Although beaver wetlands are important across North America, the importance of beaver wetlands in arid western regions may have significant importance since only 2 percent of the landscape is covered with wetland habitat, yet over 80 percent of wildlife species are dependent upon this habitat during some life stage (Hansen et al. 1995). Wetland habitats in the ten western states have declined by approximately 53 percent since European settlement (Dahl 1990) and reductions in beaver populations have added to this decline (Johnson and Chance 1974).

As an example of the amount of wetland habitat beaver provide, Munther (1982 and 1983) reported that the average creek in the northern Rockies without beaver provides between 0.8 and 1.6 ha/km of wetland habitat, whereas the same creek with beaver activity can provide over 9.6 ha/km of wetland habitat. In a similar study from Wyoming, estimates of wetland habitat in areas dominated by beaver ponds were substantially greater than those areas without beaver (McKinstry 2001). Using eight sets of aerial photographs taken from 1940 through 1986, Naiman et al. (1988) show that beaver increased their habitat use from 71 dams in 1940 to 835 dams in 1986. Less than 1% of the study area was impounded by beaver in 1940, as compared with 13% in 1986. Increasing wetland habitat has value in its self; however, there are many ecological functions and services associated with wetland habitat that also have economic value.

WATERFOWL AND AVIAN PRODUCTION

In western states where wetland habitat is limited, beaver are especially important to waterfowl and avian production. Waterfowl use beaver ponds for a variety of reasons: nesting, brood rearing, stop overs during migration, and feeding. Bird species, including neotropical migratory birds, typically associated with riparian habitat were found in more abundance and greater diversity near beaver impacted areas than in unmodified waterways (Bulluck and Rowe 2006; Cooke and Zack 2008). McKinstry et al. (2001) found that stream reaches with beaver ponds averaged 7.5 ducks/km of stream, while similar stream reaches without beaver ponds only averaged 0.1 ducks/km of stream. In central Idaho, Medin and Clary (1990) found total bird density in beaver pond habitat to be three times higher than adjacent riparian habitat without beaver. They also reported total bird biomass, bird species richness, and bird species diversity were 3.49, 3.25, and 1.67 times higher in beaver pond habitat.

These increases in waterfowl and avian production provide a variety of recreational opportunities and have both direct and indirect economic values. Waterfowl hunting and birding generate a lot of income for towns and areas that are based on recreational and tourism industries. In 2006, the U.S. Fish and Wildlife Service estimated that ~1.3 million people hunted waterfowl in the United States, spending ~$900 million on trip and equipment expenditures (Carver 2008). Other direct economic values of waterfowl and other birds come from bird watchers and bird photographers. It is estimated that there are over eight million bird watchers and over three million people who photograph birds or wildlife in the United States (Johnsgard 2010), all spending money on travel and equipment in their pursuit of these recreational activities. In addition to direct use values, there are also indirect use values associated with increasing bird populations: option, bequest, and existence values. The value of increasing species diversity is hard to measure in terms of dollars, but nonetheless important in determining the total economic worth.

FISH PRODUCTION

There are many economic reasons why fish production and sustainable fish populations are important. On the west coast of North America, anadromous fish species such as Chinook (*Oncorhynchus tshawytscha*) and Coho (*O. kisutch*) salmon are important commercial fisheries and a multi-million a year industry (Eggers and Carroll 2012). For example, in the state of Alaska during 2011, Chinook salmon received an exvessel price of $17.7 million based on harvests of 4.6 million pounds and an average price of $3.80/lb (Eggers and Carroll 2012). In 2009 ~9.9 million pounds of Chinook salmon were harvested from U.S. and Canadian fisheries (NOAA-FishWatch). In the state of Alaska during 2011, the initial fish ticket value for the Coho salmon harvest was $16.4 million based on harvests of 13.8 million pounds and an average price of $1.27/lb (Eggers and Carroll 2012). In 2009 the U.S Coho salmon harvest totaled 32.9 million pounds (NOAA-FishWatch). This is an example of only two fish species, representing a small fraction of the total area where commercial fishing takes place.

Chinook and Coho salmon fisheries are not only economically important for commercial fisheries, but they are also economically important for recreational fishing. The economic benefits society accrues from recreational fishing are typically far greater than economic benefits derived from commercial fishing since the consumer surplus for each fish caught is typically greater than the angler's expenditures. To show the importance and economic value of sport fishing, southeastern Alaska allocated 11.6% (54,515 fish) of the total Chinook salmon harvest to sport fishing in 2011 (Eggers and Carroll 2012). These 54,515 fish, if caught commercially would have generated ~$2.05 million. Based on many studies looking at the economic benefits of sport fishing, these 54,515 fish generate more value through recreational fishing than commercial fishing (Layman et al. 1996; Helvoigt and Charlton 2009; Thomson and Speir 2011). Sport fishing activities generate many different sources of expenditures and incomes, benefiting many people and providing an economic incentive to properly manage fish populations.

In a study done by Thomson and Speir (2011) in the Klamath River basin, current in-river conditions (presence of four dams) were compared against two alternative actions: 1) full removal of the four dams in the river; 2) partial removal of the four dams in the river. All of the following results are with the current conditions and presence of the four dams; full removal of the four dams increase total economic benefit by $126,400 per year and three more jobs (Thomson and Speir 2011). Average expenditures per angler day (for lodging, food, gasoline for transportation to/from the fishing site, fishing gear, boat fuel, guide fees) for Chinook and Coho salmon in the Klamath River basin were estimated at $66.72 (2012 dollars) (Thomson and Speir 2011). With 24,683 angler days, Thomson and Speir (2011) estimate the economic impact of fishing for Chinook and Coho salmon in the Klamath River basin to total ~$1.647 million per year (2012 dollars). They also report that these expenditures generate 34 jobs, $0.93 million in income, and $2.01 million in output on an annual basis (Thomson and Speir 2011).

A good example of the positive impacts beavers have on fish populations was found in a study done by Pollock et al. (2004) in the Stillaguamish River in Washington. In their study, current and historic distributions of beaver ponds and other Coho salmon rearing habitat were assessed and it was found that the greatest reduction in Coho salmon smolt production capacity originated from the extensive loss of beaver ponds. They estimated the current abundance of beaver ponds to be 0.49 km^2, 0.03% of the watershed, compared to a historical estimate of 9.3 km^2, 0.5% of the watershed. Historically, beaver ponds were estimated to have a smolt production potential of 7.6 million juveniles, accounting for 79% of the total smolt production potential in the watershed. Currently, beaver ponds have a total smolt production potential of only 537,000, a reduction from historic levels by 93%. Most, 92%, of the overall Coho smolt reduction resulted from the loss of beaver ponds. The unique ability of beaver to modify ecosystems to the extent that fish production can be increased so dramatically has significant economic benefits associated with it.

The influence of beaver activity on fish production is of particular interest due to the endangered and threatened status of certain fish species (e.g., Chinook and Coho salmon) under the Endangered Species Act. Not only are these fish important economically for direct use values like commercial and recreational fishing, but they are also important for non-use values (Helvoigt and Charlton 2009). Many people contribute money, time, and other resources to benefit native species and intact, undisturbed ecosystems with the desire to protect them for future generations or future use. While, other people want to protect native species and landscapes for the sole purpose that such things should exist, even if they themselves will never see or make use of them. Based on the results of peer-reviewed, published studies and data from household surveys, Helvoigt and Charlton (2009) estimate the implicit value of all Rogue River salmon and steelhead runs to be ~$1.5 billion, significantly greater than the total use value of Rogue River salmon which they estimated to be $17.36 million annually. When computing the economic value of natural resources, both use and non-use values should be considered, calculated, and presented to policy makers and the public to ensure actions and decisions are based on the best available information.

WATER STORAGE AND FLOOD CONTROL

Beaver dams and ponds create wetland environments which act as reservoirs for storing water, filtering systems improving water quality, and natural buffers reducing the frequency and intensity of floods (Skinner et al. 1984; Kay 1994; Gurnell 1998). As discussed earlier, The Lands Council in eastern Washington concluded that 2.2 to 4.1 million acre feet of water could be stored on the 9,800 miles of stream that were found to be suitable for beaver occupation (Walker et al. 2010). The ability of beaver to store large amounts of water across the landscape could prevent construction and maintenance costs of building new reservoirs. Other costs associated with dam and reservoir construction include land acquisition, administrative costs, and possibly the relocation of families, cemeteries, and infrastructure. In a study on dams in the contiguous United States it was found that the average marginal cost of water stored in reservoirs is $39/acre foot (Frederick et al. 1997). For the Pacific Northwest the average marginal cost is $55/acre foot (Frederick et al. 1997). Using estimates from The Lands Council and Frederick (1997), the economic value of storing water using beaver ponds in eastern Washington range from $121 to $225.5 million.

Flood damages in the U.S. average $2 billion each year, causing significant loss of life and property (National Oceanic and Atmospheric Administration). Although these damages are mostly from large rivers, a series of beaver dams across the landscape higher in a watershed can have a significant effect (Grasse 1951), reducing downstream impacts. Beaver dams decrease peak discharge during a runoff event and thereby reduce the possibility of flooding (Bergstrom 1985; Parker et al. 1985; Gurnell 1998). In a second order stream in Maryland, the creation of a 1.25 hectare beaver pond reduced the annual discharge of water by 8%. Simulation models looking at how beaver activity impacts the intensity of flooding events has shown that a single beaver pond could reduce peak flow of a two-year flood event by about 5% and that a series of several ponds could reduce peak flow by 14% (Beedle 1993). Reintroduction and restoration of beaver will not solve the problem of flooding but could help in reducing the economic damages of floods.

Even though beaver can reduce flooding they can also be the culprit. In urban and developed areas beaver have the potential to plug culverts or impound water against road beds, causing flooding in undesirable areas and economic losses. Flooding and loss of valuable pasture and cropland creates economic hardships for certain individuals. Although beaver can have negative impacts through dam-building, there have been many successful methods developed for handling these situations, limiting economic losses: instillation of a pipe at the bottom of a dam and regulating water levels (Roblee 1984; Miller and Yarrow 1994); exclusion by fencing or screening devices (de Almeida 1987; Miller and Yarrow 1994; Finnigan and Marshall 1997; Jensen et al. 1999). Sherri Tippie and Mary O'Brien have put together a valuable manual for dealing with "problem" beavers (Tippie and O'Brien 2010). Their manual, 'Working with Beaver for Better Habitat Naturally', includes different methodologies and instruction and material guides on how to construct several kinds of devices to solve and alleviate beaver related issues. The application of these methodologies will help prevent loss of property, structural damages, and economic losses from beaver dam building, ponding, and flooding. Preventing economic losses may shift some of the negative public perceptions of beaver as rodents causing damage to a more positive image of a species we can live with.

WATER QUALITY AND SEDIMENTATION

The value of increasing water quality and sediment accumulation from beaver activity can also be demonstrated in economic terms. Wetlands created behind beaver dams act as a natural filtration process, removing excess nutrients and pollutants and making it healthier for drinking water and human consumption downstream (Skinner et al. 1984; Collen and Gibson 2001). For example, the Congaree Bottomland Hardwood Swamp in South Carolina removes a quantity of pollutants from the watershed equivalent to that which would be removed by a $5 million treatment plant (EPA832-R-93-005). In a report by ECONorthwest, they estimate that pollutant removal through sediment capture from beaver ponds were worth $100,000 per year per percent improvement (Buckley et al. 2011). Although this estimate comes from the Escalante River basin in southern Utah, it provides insight to the approximate value of such services from beaver.

By reducing peak discharge and stream velocity, beaver dams can reduce the erosion potential of a runoff event (Apple et al. 1984; Parker 1986). The slow velocity of water behind dams creates extensive depositional areas for sediment and organic materials transported from upstream. Sediment storage behind beaver dams can be substantial and has been very well documented (Scheffer 1938; Apple 1985; Naiman et al. 1986; Butler and Malanson 1995; Pollock et al. 2007; Pollock et al. 2011). Beaver ponds in one study averaged 225 m^3 of captured sediment per pond, and as much as 5000 m^3 (Butler and Malanson 2005). In the Escalante River basin sediment storage from the average beaver pond is estimated to be 29,500 to 85,200 ft^3 throughout its lifetime, while all beaver ponds within the drainage are estimated to store 204 to 549 million ft^3 of sediment annually (Buckley et al. 2011).

As beaver dams capture sediment and other material, they can generate multiple economic benefits. In Utah, sediment retention has been estimated to have an economic worth of $2 per cubic yard (Utah Department of Natural Resources 2010). Assuming all of the sediment retained by beaver activity in the Escalante basin would be dredged if allowed to flow through the basin, dredging costs of $15 to $40 million per year could be avoided (Buckley et al. 2011). Currently, there is a proposal to increase the size of the Wide Hollow Dam to recover the reservoirs original storage capacity which has been lost to accumulation of 43.5 million ft^3 of sediment (U.S Army Corps of Engineers 2010). The estimated cost of this project is about $13 million (Utah Department of Natural Resources 2010). The Utah Department of Natural Resources estimates that in 2008, agricultural production relying on the Wide Hollow Reservoir experienced $270,000 less net farm income than had the reservoir been able to reach its original capacity of 2,400 acre-feet. Factoring in the economic multiplier associated with agricultural production, it's estimated nearly $720,000 in income was lost throughout the area due to the reservoir's sediment build up (Utah Department of Natural Resources 2010). Beaver activity upstream of the reservoir could reduce these future losses by preventing further decreases in the reservoir's water storage capacity.

The storage loss due to reservoir sedimentation has been found to exceed the storage added worldwide by the mid-1990s (Annandale 2006). Recovery of this lost storage is estimated to range between US$ 10 billion and US$ 20 billion per year, not accounting for the growth in world population (Annandale 2006). While beaver dams will likely not prevent all sedimentation in reservoirs, estimates suggest that they could substantially reduce sedimentation rates. By preventing sedimentation, beaver dams will likely reduce the future costs associated with reservoir maintenance and reduce the amount of revenue lost by agricultural and other related industries due to diminished reservoir capacity.

CORE COMPETENCY – POLICY AND ADMINISTRATIVE CONCERNS

Studies suggest that rapid recolonization, dam construction, and changes in physical habitat occur after beaver reintroduction as long as the animals are not harvested or consumed by predators (Apple 1985; Albert and Trimble 2000; McKinstry et al. 2001; McKinstry and Anderson 2002). Merely reducing or banning commercial or recreational harvest (trapping) of beavers has led to the slow recolonization of this species in many areas of the United States (Pollock et al. 2004). However, many western states allow commercial and recreational beaver trapping, in spite of the benefits associated with dam-building beaver, limiting recolonization into former habitats and expansion of beaver populations. Additionally, public agencies and land management organizations have recognized the ecologically important role of beaver, giving beaver "special" status (e.g., USFS management indicator species (MIS)), or writing management plans to promote sustainable beaver populations (e.g., Beaver Management Strategy-Malheur National Forest and the Keystone Project 2007; Utah Beaver Management Plan 2010). Policy and administrative concerns relating to beaver will play an important role in the management of beaver populations and habitat, but will also be an important factor determining how beaver are perceived by society and the values attributed to functioning beaver populations.

The protection and management status of beaver vary by state and federal agency as well as across states. Beaver trapping is regulated by state agencies with each state having different trapping regulations, but most restrict trapping seasonally and geographically, and some have bag limits. Arizona, New Mexico, and Oregon ban trapping on most national forests and several other states have closed particular streams and rivers on federal lands. Beaver are managed under a variety of trapping regulations, sometimes it seems in contradiction to the beneficial and protective status beaver can receive within an individual state. In Oregon, the Oregon Department of Fish and Wildlife notes many benefits to having beaver on the landscape on their website and has even created a document to assist landowners in living and dealing with beaver (Oregon Department of Fish and Wildlife) and also a document outlining guidelines for relocation of beaver (Oregon Department of Fish and Wildlife 2012). In spite of this, Oregon lists beaver as a predator on private land and beaver may be lethally removed without a permit by landowners. In this scenario, the state of Oregon is unaware of how many beaver are being removed from the landscape annually, underestimating annual harvest rates. In Utah, the situation is similar; however, goals and objectives have been set for both beaver population expansion and harvest/trapping regulations. The Utah Division of Wildlife Resources developed a beaver management plan in 2010 with the purpose of expanding the current distribution to its historic range where appropriate. Additionally, one of the objectives is to improve riparian habitats through translocating beaver onto suitable public and/or private land. However, the Utah Division of Wildlife Resources estimates that 2,962 beaver were harvested in 2010 and 2011. Even though goals and objectives are developed for both consumptive purposes of beaver and restorative and protective purposes, they appear to be contradictory to each other, demonstrating how difficult it is to administer effective policy for the management of natural resources given a diverse group of users.

Public opinion on beaver management varies, especially between those who are directly impacted from beaver activity and those who are not. Groups of people who are enduring economic losses from beaver activity are more likely to accept lethal control methods of beaver. Although public opinion on beaver management and control methods vary, there appears to be a shift in policy towards more beaver protection and acceptance. In November 1996, Colorado passed Amendment 14 which banned the use of leg hold and kill traps throughout the state, reducing the trapping of furbearers. Even though regulations that control or ban recreational trapping in many jurisdictions, these policies usually do not apply to landowners who are protecting private property. In the state of Washington, House Bill 2349 concerning the management of beavers has been recently passed by both the Senate and the House. House Bill 2349 will require the Washington Department of Fish and Wildlife (WDFW) to:

- live trap and relocate nuisance beaver when the option is available, in part by keeping up-to-date records of nuisance beaver complaints and requests for beaver relocation
- maintain public records of beaver populations to be used to create a map of population dynamics
- offer a relocation permit to increase the use of relocation, not lethal control, of nuisance beavers to appropriate areas (i.e., east of the Cascades)
- Establish a long-term plan for better beaver management that will:
    - Improve beaver damage management
    - Increase use of beaver for watershed restoration
    - Minimize risk of disease/aquatic invasive spreading from beaver relocation
    - Increase public awareness of the benefits of beaver

Killing or relocation of nuisance beaver is allowed in many states; however, a permit is usually required. House Bill 2349 in Washington allows beaver to be relocated without a permit, removing "red tape" and hesitancy of landowners to relocate beaver, avoiding lethal control methods. Besides relocation, many other methods exist for dealing with nuisance beaver. Increasing public awareness and environmental education on the ecosystem benefits derived from beaver will play a major role in keeping beaver on the landscape, especially where they already exist, and getting society to learn to live with beaver and accept the good with the bad. Although there are negative impacts from beaver (e.g., plugging culverts, flooding pasture and cropland, damming irrigation ditches), lethal methods should be a last resort option since positive impacts outweigh the negative impacts. Change in public opinion and perception of what constitutes negative impacts will have considerable ramifications to beaver and their habitat. Several non-profit groups working on public outreach and education programs include the Grand Canyon Trust working on the Colorado Plateau, The Lands Council working in eastern Washington, and Wild Earth Guardians working across the west. Wrapping trees to detract beaver chewing, installing pond levelers to avoid flooding, and installing beaver deceivers and castor mastors are all creative, innovative ways that have been developed to learn to live with beaver (Tippie and O'Brien 2010; Oregon Department of Fish and Wildlife).

As discussed in previous sections, habitat created by beaver is an important factor affecting many fish species, including fish listed as endangered or threatened under the Endangered Species Act. Bull trout, Chinook salmon, Coho salmon, and steelhead (all listed under ESA in at least part of their range) have all been shown to use beaver created habitat, sometimes disproportionately to its availability (Bustard and Narver 1975; Murphy et al. 1989; Jakober et al. 1998; Pollock et al. 2004; Lindstrom and Hubert 2004; Hood 2012). Protecting natural system functions (e.g., water filtration through wetlands, flood attenuation, sediment storage) and the diversity of habitats needed by these species is just as important as direct protection of the species itself. Specific habitat types or natural communities (e.g., fen meadows) can be just as endangered and rare as a particular species but receive much less attention than individual species. Most laws focus on individual species and not on assemblages of species or natural communities, especially after they have become threatened or endangered, which may be too late to stop or reverse the decline of a species. More policy and regulation should be placed on protection of entire ecosystems and the connections between them rather than policy based on individual species. Habitat protection has the possibility of providing for multiple species and also for providing ecosystem services, as in the case of beaver ponds, which can benefit both humans and fish and wildlife species. Policies focused on habitat protection would require tradeoffs to other land uses. This type of regulation would be based on preventative measures rather than reactionary measures, which could pay dividends in the long run in both species protection and in the resources used for species protection.

With a diversity of state, federal, and private organizations all working on beaver management projects comes a need for a way for all involved organizations to share information, experiences, and to learn from each other, all towards the betterment of beaver and riparian resources. Knowledge across groups about nuisance beaver and areas that are void of beaver that are in need of restoration or where habitat is available to beaver will ultimately provide more effective reintroduction and relocation policies. Better collaboration amongst agencies and private groups will allow for a more thorough and efficient management of beaver and riparian habitats and also a more wise use of resources. In the long term, both time and money could be saved with a collaborative beaver management effort. In the short term, time and effort must be spent for the coordination of a centralized method to better communicate beaver management on large scales. Meetings, workshops, and/or short courses dedicated to the appreciation, understanding, and management of beaver is a good starting point and will need to continue to develop and expand for the success of an effective beaver management strategy.

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APPENDICES

APPENDIX A – PHOTOS FROM PIBO EM SHOWING DIVERSITY OF BEAVER OCCUPIED SITES

Small Creek, Panhandle National Forest

Salmon River, Sawtooth National Forest


Hollow Creek, Colville National Forest


Timber Creek, Salmon-Challis National Forest


Smith Creek, Wallowa-Whitman National Forest


Huckleberry Creek, Sawtooth National Forest