Dear Director Macdonald,

I have briefly reviewed several of the documents supporting the Oregon Global Warming Commission meeting to be held on July 28. I am a native Oregonian, a professor of environmental geography at Sonoma State University, and have lived in California for the past 12 years because this is where the work is. I hope to move back to Eugene in the next two years.

I am writing to ask that you consider the two attached publications and/or recommend them to the appropriate group for inclusion in the meeting's discussion. The first article was published in 2016 and reviews the potential benefits beaver could provide in mitigating and adapting landscapes to help us deal with climate change. Though the article is specific to California, much of this is relevant to Oregon as well. Beaver can help create more resilient waterscapes and aquatic habitat, inhibit wildfire spread, and sequester significant amounts of carbon. The second article was published in 2017 and details some of the processes and practices I identified in Oregon which inhibit talking about beaver and allowing beaver to live once again amid Oregon's landscapes.

I would be very happy to continue this conversation if you are interested. I implore you to reconsider the omission of beaver as climate change partners. They do pose some challenges, and we have developed simple, low cost technologies to address those.

Thank you for your consideration - Jeff

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Potential mitigation of and adaptation to climate-driven changes in California's highlands through increased beaver populations

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Climate models forecast significant changes in California's temperature and precipitation patterns. Those changes are likely to affect fluvial and riparian habitat. Across the American West several researchers and civil society groups promote increased beaver (*Castor canadensis*) presence as a means to moderate such changes. This study reviews three literatures in an effort to evaluate the potential for beaver to adapt to and to mitigate anticipated changes in California's higher elevation land- and waterscapes. First, I provide a synopsis of modeled changes in temperatures and precipitation. Forecasts agree that temperatures will continue to increase, to 1.5–4.0° C by 2060; however, forecasts for precipitation are more variable in sign and among models. Second, researchers anticipate climate-driven changes in stream and riparian areas and project that snowpacks and summer flows will continue to decline, winter and spring flood magnitudes will increase, spring stream recession will likely continue to occur earlier and more quickly, and highland fires will be more extensive. Each of these changes has important implications for wildlife and public lands managers. A third focus reviews beaver natural histories and finds that where beaver dams are persistent, they may sequester sediment and create wet meadows that can moderate floods, augment early summer baseflows, sequester carbon in soils and standing biomass, decrease ecological problems posed by earlier spring stream recession, and potentially help cool early summer and post-wildfire stream temperatures. However, due in part to currently limited habitat suitability and to conflicts with other human interests, mitigation would likely be most meaningful on local rather than statewide scales.

Key words: beaver, *Castor canadensis*, climate forecasts, California highlands, hydrological changes, mitigation, wetland restoration

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In California, meteorological and hydrological records indicate that the state is already experiencing changes attributable to anthropogenic climate change (Barnett et al. 2008, Pierce et al. 2008, Bonfils et al. 2008, Das et al. 2009, Hidalgo et al. 2009). As a result, the State's snowpacks are melting earlier (Kapnick and Hall 2009), and winter precipitation is falling increasingly as rain rather than snow (Hayhoe et al. 2004, Cayan et al. 2008). Several groups in the American West (King County in Washington, The Beaver Advocacy Committee in Oregon, and in California The Beaver Work Group and Martinez Beavers) are exploring increased beaver (*Castor canadensis*) presence as a way to restore fluvial and riparian habitat and increase resilience against the effects of climate change (Apple et al. 1985, Trimble and Albert 2000, Pollock et al. 2012, DeVries et al. 2012).

This article focuses on California's highlands (the Sierra Nevada and northern coastal ranges, and the Lassen, Shasta, and Trinity regions) as that is the site of most of the State's precipitation and nearly all snowfall that currently provides about one-third of all consumed water (Gasith and Resh 1999). Furthermore, because much of the land in the areas is publicly held, population expansion and damage caused by beaver works can be effectively managed. The paper reviews extant literature towards three ends. First I introduce climate models, the scenarios for future greenhouse gas (GHG) emissions they employ, and then present forecast changes in temperatures and precipitation. Next, I extend those forecasts to examine anticipated effects on fluvial and riparian form, function, and habitat that could potentially be affected by increased beaver populations. Finally, I review what is known of beaver natural history in an effort to characterize the potential adaptations and mitigations an increased beaver population could provide. California's highlands offer somewhat unique climate and geology. Findings from studies conducted east of the Pacific Rim are treated accordingly.

Climate Models and Forecast

Model ensembles and scenarios.—Following best practices established by the Intergovernmental Panel on Climate Change (IPCC) the studies reviewed here create ensemble forecasts using between 3 and 16 global circulation models (GCMs). Those models can be adjusted to provide varying spatial resolution. At their coarsest, each cell includes three degrees of longitude and three degrees of latitude, and so treats areas 160 by 330 kilometers as homogenous. Required computing power increases rapidly as resolution is increased. As a compromise researchers may use statistical resolution that compares projections made by numerous models and creates a probability distribution for more localized areas of interest. Alternatively, dynamical resolution treats the parcels surrounding the area of interest as boundary conditions and then increases resolution only for the study area. Most of the studies reviewed here have been downscaled (i.e., increased resolution) using one or both of these methods.

In order to minimize global climate response uncertainty (Costa-Cabral et al. 2013), modelers use representative CO_2 concentration pathways (RCPs)—these are referred to as scenarios. The models referenced in the following discussion employ two business-as-usual, high GHG scenarios; either the A2 scenario published in 2002 that projects atmospheric carbon equivalent to reach 800–830 ppm in the year 2100, or the more recent AR5 8.5 scenario that places CO_2 equivalent at 1250–1380 ppm in 2100.

Modelled forecasts for temperature and precipitation.—Models are more consistent in temperature forecast than those for changes in precipitation. Together, increased warming in winter and spring is already causing diminished summer streamflow across the West (Stewart et al. 2004, 2005), a phenomenon modeled to continue (Hamlet et al. 2005, Barnett et al. 2008). Diffenbaugh et al. (2015) reported that even though rainfall anomalies have not increased in California over the past two decades, warming temperatures have decreased water availability significantly, and forecast increased drought conditions as a result.

Models agree that highland temperatures will rise through the end of the century (Table 1; Pierce et al. 2013). This is the most vigorous study published at the time of writing this review. Pierce et al. (2013) employed the SRES A2 GHG scenario and employed both statistical and dynamical downscaling to forecast changes for the 2060s relative to a 1985–1994 base period.

Precipitation changes forecast by Pierce et al. (2013) and Walsh et al. (2014) are presented in Table 2. The latter used the updated and higher greenhouse gas AR5 8.5 scenario.

Table 1.—Forecast increases in mean seasonal temperature (°C) of highland regions of California for the period 2060–2069 when compared to the relative historic base period of 1985–1994. The model used the high CO_2 scenario (SRES – A2; from Pierce et al. 2013).

	Highland Region of California			
Season	Sierra Nevada	Shasta Region	North Coast	Central and South Coast
Winter	1.5–2.1	1.7	1.5–2.2	1.8
Spring	2.0–3.0	1.9	1.4–2.0	2.1
Summer	3.0–4.0	2.9	2.0	2.3

Table 2.—Percent changes in seasonal precipitation forecast to occur in the highland regions of California under high CO_2 scenarios (data interpreted from Piece et al 2013, Walsh et al. 2014; N= north, S=south).

	Season		
Highland Region	Winter	Spring	Summer
Northern California[a]	0 ⇔ + 10	-10 ⇔ -20 N ⇔ S	- 30 ⇔ - 10 N ⇔ S
Southern California[a]	0 ⇔ - 10 N ⇔ S	- 30 ⇔ - 40 N ⇔ S	0 ⇔ +10
Shasta Region[b]	+ 9	- 11	- 29
North Coast[b]	+ 7 ⇔ - 2 N ⇔ S	- 10 ⇔ - 18 N ⇔ S	- 32 ⇔ - 13 N ⇔ S
Sierra Nevada[b]	- 5	- 11 ⇔ - 19 N ⇔ S	- 23 ⇔ + 59 N ⇔ S
Central and South Coast[b]	+ 1 ⇔ - 5 N ⇔ S	- 19	- 13 ⇔ +50 N ⇔ S

[a]Forecast under the AR5 8.5 high CO_2 scenario for 2070–2100 compared to the relative historic base period of 1970–2000 without downscaling (from Walsh et al. 2014).
[b]Forecast percent increase in mean seasonal temperature by highland region for the 2060s compared to the relative historic base period of 1985–1994. The model uses the high CO_2 scenario (SRES – A2) and statistical and dynamical downscaling (from Pierce et al. 2013; N= north, S=south)

That group forecast changes for the period 2070–2100 relative to the historic base period 1970–2000. Though not downscaled, these results are similar in sign to findings by Pierce et al. (2013); however, the Walsh et al. study generally forecast a greater increase in winter precipitation and a less-marked decrease in spring and summer precipitation.

Climate-driven Changes in Fluvial and Riparian Areas

These forecast changes in climatic boundary conditions will likely cause changes in several landscape aspects that beaver could potentially moderate. The following discussion reviews the extant literature on climate driven changes to stream flow timing and magnitude, channel morphology, stream temperatures, fire regimes, and meadows above 1,200 meters in elevation.

Snow to rain.—California's snowpacks provide about one-third of the water consumed in that state while also supplying stream flows that are critically important to dry-season habitats. Several studies have sought to quantify the magnitude of snow water equivalent (SWE) loss. Modeling by Cayan et al. (2008) suggested that the greatest diminution of snowpack will occur at elevations below 1,300 meters. Using the SRES A2 high emissions scenario (830 ppm), the modelers used data from the 1990s as a base period. The model forecast that SWE on April 1 (historically the beginning of spring melt) will decline by 37–42% by mid-century and 70–80% by 2100, thereby decreasing spring spate and summer streamflow.

A study by Das et al. (2011) suggested that warmer winters and springs will increase evapotranspiration and that sublimation may further diminish snowpacks and spring runoff. Using an ensemble of 16 GCMs, assuming a 3°C temperature increase and holding precipitation constant, they forecast that these in situ losses of snowpack would decrease April–September flows in the northern and southern Sierra Nevada by 1.8 and 3.6%, respectively, and October–March flows by 2.1% and 3.1%. Illustrating the effects of model variability, Costa-Cabral et al. (2012) ran a similar simulation and reported no relation between temperature and sublimation-evapotranspiration due to earlier snowmelt-runoff.

Beyond a diminution of this natural water reservoir, shifts from snow to increased rain suggest two related sets of problems: increased flooding and issues related to earlier snowmelt recession (Kapnick and Hall 2009). Each of these processes in turn has direct and indirect effects on ecological and human systems.

Flooding.—Hydrographic records indicate that flood magnitudes in California have increased since the 1920s. In a national study Peterson et al. (2013) found that decadal high flow magnitudes have increased at average decadal rates of 9% in northern California, 8% in the southern Sierra Nevada, and 3% on the central coast and the central Sierra Nevada. Several investigators examined increased flood magnitude under higher GHG accumulation. Cayan and Riddle (1992) reported that in California the largest floods are associated with winter-spring circulation over the central and eastern Pacific, and are specifically caused by atmospheric rivers (see also Ralph et al. 2006, Neiman et al. 2007). Again, atmospheric conditions over the Pacific are influenced by numerous factors and model ensemble results are not in strong agreement on forecast conditions. As discussed above, however, models strongly agree on the sign and trend of temperatures in the region and uniformly forecast warming. As a result, storms will be warmer and will produce less snow and more rain (Knowles et al. 2006, Das et al. 2009), producing greater flood magnitudes, particularly during rain-on-snow events.

Several other teams have modeled future flood characteristics. Das et al. (2011) used three GCMs calibrated through precasting (forecasting past flooding given historic climatic parameters) and then input results through a variable infiltration capacity hydrologic model. All three models forecast significant increases in flood magnitudes. While one model forecast decreased flood frequency, two found increased frequency. In 2012, Wehner reported that adding elevation data to a coordinated eight regional model ensemble significantly improved its precast performance. The newly parameterized ensemble compared conditions for North America in the period 2038–2070 to a 1968–1999 base period, and forecast a 5–10% increase in winter, a 10–20% decrease in spring precipitation, a 0–5% increase in winter, and a 0–15% decrease in spring maximum daily precipitation (i.e., flood magnitude).

In 2013, Dominguez et al. employed an ensemble of 8 GCMs to model changes in winter precipitation for the western United States. Comparing forecasts for the period from 2038–2070 with a base period from 1968–1999, they found a 12.6% increase in the magnitude of 20-year floods and an increase of 14.4% in 50-year floods. More generally, however, the models rendered a high probability forecast for a 7.5% decrease in average winter precipitation for the Sierra Nevada and southern California, and slight increases in precipitation for northern coastal California.

Using an ensemble of 16 GCMs and a high carbon emission SRES A2 scenario Das et al. (2013) found that flood magnitudes in the western Sierra Nevada will increase regardless of trends in mean precipitation (see also Maurer et al. 2007). The investigators found that magnitudes would increase beyond current variability as early as 2035. Compared with simulated historic 50-year flood events, the ensemble forecasts progressive increases of flood magnitude of 30–90% in the northern Sierra Nevada and 50–100% in the southern Sierra Nevada by 2100.

Again employing an ensemble of 16 GCMs and both statistical and dynamical downscaling, Pierce et al. (2013) forecast changes in three day accumulation for 100-year flood events (Table 3). Though the forecasts manifest an expected degree of variability, they produced a consensus of sign regarding flood magnitude, which is forecast to increase. There is little consensus regarding trends in total annual rainfall among California's various highland regions. An increase of winter flood events will increase the geomorphic dynamism of stream channels on a decadal scale.

Table 3.—Forecast changes in maximum three-day precipitation events in California's highland regions for the period 2060–2069 when compared to the base period of 1985–1994 (data interpreted from Pierce et al. 2013).

Highland Region	Current Accumulation (mm)	Forecast Accumulation (mm)	Increased Accumulation (mm)
Sierra Nevada	280	370	90
NE California	90	180	90
Shasta	180	300	120
North Coast	240	360	120
Central Coast	165	220	55
South Coast	160	190	30

Recession.—On an annual scale, spring spates were forecast to occur earlier and to decrease in magnitude and duration. Many species are adapted to the specific timing of the spate (Jager et al. 1999, Marchetti and Moyle 2001, Lytle and Poff 2004, Jowett et al. 2005), and exploit a typically slowly retreating moist fluvial margin (Kupferberg 1996, Freeman et al. 2001). More rapid recession will decrease riparian seeding (Shafroth et al. 1998) and nutrient loading (Rood et al. 1995, Langhans and Tockner 2006), decrease primary productivity (Acs and Kiss 1993) and arthropod abundance (Paetzold et al. 2008), decrease salmonid spawning activity (Moir et al. 2006), and weaken other trophic chains (Nakano et al. 1999, Yarnell et al. 2010). Geomorphically, rapid recession is expected to produce steeper bars and so decreased moist transitional area, increased water temperatures, and increased stranding of young amphibians (Kupferberg et al. 2008).

The corollary condition, decreased magnitude of peak spring flow, is expected to decrease the area of aquatic habitat through channel narrowing and loss of wetted side channels (Ligon et al. 1995, Van Steeter and Pitlick 1998) leading to decreases in diversity and abundance of macro-invertebrates and algal production (Peterson 1996, Jowett et al. 2005), which are important food sources for higher trophic levels. Decreased erosion and deposition will decrease lateral channel migration, decreasing channel elevation—and so habitat—variability (Parker et al. 2003, Shields et al. 2000), which may enhance riparian encroachment by woody vegetation (Lind et al. 1996, Shafroth et al. 2002). In addition, earlier melt will result in increased water temperatures, thereby favoring species adapted to warm water and diminishing cold water adapted species such as salmonids (Kupferberg 1996, Jager et al. 1999).

Stream temperatures.—Sub-alpine streams are also expected to warm as a result of atmospheric temperature shifts. Null et al. (2013) employed a regional equilibrium temperature modeling approach that incorporated mechanistic heat exchange between atmosphere and water to model changes in the Feather River as it flows west from the northern Sierra Nevada. The investigators found that at elevations below 1,000 and above 3,000 meters, stream temperatures rise about 1.5°C for each 2°C increase in mean average annual atmospheric temperature. Streams between 1,000 and 3,000 meters responded more strongly at about 1.8°C for each 2°C increase in atmospheric temperature; this is due largely to decreases in snowpack. Currently, July temperatures in the Feather River exceed 21°C in only the lower 30 km (20%) of that stream. However, Null et al. (2013) reported that with atmospheric temperature increases of 2, 4, and 6°C, that threshold is exceeded in 57%, 91%, and 99.3% of the stream, respectively. The authors also noted that the effect of increased atmospheric temperatures are moderated in that watershed through extensive basalt layers underlying the stream that produce significant hyporheic flows that help cool stream temperatures.

Fish.—For salmonids (anadromous and resident trout and salmon) these changes in temperature and flow regime pose particular problems. The upper end of the optimal temperature range for these indicator species is 19°C. The maximum sustained water temperature tolerated by anadromous salmonids is 24°C (Eaton and Scheller 1996). However, at certain stages of their life cycle—eggs and alevin—these fish require lower temperatures (Myrick and Cech 2001), and salmonids exhibit stress at sustained temperatures above 21°C (McCullough 1999, Myrick and Cech 2001). Null et al.'s (2013) forecast has much of the Feather River exceeding 21°C by 2070–2099.

The forecast geomorphic changes are also expected to affect fish habitats. Mantua et al. (2010) examined the effects of expected higher winter and lower summer streamflows on anadromous salmonids in Washington State. They noted that for young Coho the two most important hydrological factors in survival are first year summer temperatures and more importantly, refuges from winter high streamflows in their second winter. Those refuges are commonly found in side channels that several studies suggested will diminish under forecast flow regimes (Ligon et al. 1995, Van Steeter and Pitlick 1998, Shields et al. 2000, Parker et al. 2003, Pollock et al. 2003).

Dam reservoir management.—Changes in precipitation, snowmelt recession, and flood regimes in highland areas pose particular problems for the management of winter and spring pool levels in California's dam system, both for flood control and for power generation (Moser et al. 2012). Das et al. (2013) observed that increased probability of larger flood events will require dams to maintain lower pools in the future to accommodate potential floods. However, should a flood not occur, dam systems will begin the dry season with pools potentially much below maximum storage. Warmer summers will increase electrical demand while summer flows into reservoirs are forecast to decrease.

Fire.—As the West warms, wildfires may become more frequent or more extensive, or both. Westerling et al. (2011) developed a three-model wildfire ensemble to forecast fire extent for California. Contrasting the optimistic SRES B1 scenario with the higher A2 emission pathway against a 1970s base period they found only moderate differences between the two scenarios and for year 2020 forecast an increase of statewide area burned at 10–20%. For 2050 and 2085 the B1 scenario forecast increases of only about 5% for each interval. However, the A2 scenario yields increases up to 38% in 2050 and 40–70% in 2085. While these increases seem somewhat moderate, a closer look at sub-regions of California yields more meaningful results. All models forecast little or no increase in area burned south of Monterey, Kings, Tulare, and Inyo counties, the Central Valley, and the mountains of the central coast. However, across the forested areas of the Sierra, all of northern California including the coastal mountains north of Marin County, the area burned is forecast to increase by 100–300%.

Increased fire extent suggests increased sediment mobilization and stream temperatures. Ice et al. (2004) reported that stream sedimentation and nutrient mobilization (with the exception of phosphorus which may volatilize) increase with fire severity (temperature and duration) and landscape gradient. They concluded that, "Long-term erosion rates in fire prone landscapes may be higher than often believed, and post-fire sediment pulses can have both positive [increased downstream channel complexity in later years] and negative effects" (Ice et al. 2004:20). The latter are related to the mobilization of fine gained sediment that can degrade spawning areas and alter trophic chains. Regarding stream temperature changes, Brown and Krygier (1970) studied two comparable streams in western Oregon, one well shaded and relatively undisturbed, the other flowed through an area that was first clear-cut then slash burned. In the second stream they observed summer temperatures rising from a mean average 13°C prior to treatment to 28°C (range 26–30°C). During the treatment summer the control stream recorded temperatures of 14–15°C. In a similar study in southwestern Oregon, Amaranthus et al. (1989) reported that small stream temperatures increased from about 14°C to 21°C following shade-removing wildfires.

High meadows.—High-elevation meadows present an additional area for consideration. A wetter climate regime beginning between 2,500 and 1,200 years BP raised water tables in high meadows that favored hydric plant communities dominated by sedges, rushes, herbs, dwarfed shrubs, and grasses (Wood 1975). Unique faunal communities subsequently adapted to live in these areas. In the later 1800s and early 1900s these meadows were widely exploited by commercial pastoralists. As a result of grazing, road grading, intentional drainage, and grass crop cultivation many meadow streams have become incised and water tables have dropped so that mesic and xeric floral communities now dominate (Loheide et al. 2009). Climate change will further stress meadow hydrologies by changing mean annual flows, shifting spring spates earlier, and produce a lengthier low-flow period (Null et al. 2011). Loheide et al. (2009) suggested that earlier and shorter snowmelt recession and reduced daily fluxes in snowmelt-related streamflows will reduce groundwater recharge. Viers et al. (2013) noted that meadows between 1,500 and 3,000 meters will be most affected, and that because northern meadows generally are at lower elevations they are more vulnerable. Beaver populations in some of these areas were also reduced in the nineteenth century (James and Lanman 2013). Central to the current discussion, meadow restoration projects on the Feather River in northeastern California are providing some of the best opportunities for research into the potential for beaver to mediate some of the aforementioned changes in California's highland waterscapes.

Beavers and Climate Change Mitigation and Adaptation in California

As the following review indicates, scientific studies are limited, first in applicability and so in number, and second in quality. Most scientific study is focused on areas of North America shaped by continental or extensive alpine glaciation, or by monsoonal or otherwise moist summer seasons, and so may not provide analogs for California's highland hydrologies. Furthermore, several widely cited studies from the western United States are somewhat anecdotal and, thus, problematic.

It is important to stress that habitat initially suitable to persistent beaver occupation is limited by certain factors (Baldwin 2013). Beaver dams are more persistent when situated in wider valleys on reaches with gradients less than 6%. Although they are generalists, beavers build more dams in areas where hardwoods grow within 30 meters of stream channels. Though cross-channel dams are most typical on 1st–4th order streams, beaver also dam side channels on larger streams. No statewide suitability study has been published. Yet, as this review suggests, some of those local benefits are potentially significant.

The following discussion addresses several processes through which beavers might moderate the climate driven changes identified in the previous section. Among these are water storage, streamflow seasonality, sediment flows and storage, nutrient flows and stocks, riparian vegetation, flood events, changes in spring stream recession, and wildfire.

Water storage.—Beaver works cause water to be stored both in surface ponds and wetlands, and in subsurface or hyporheic flows. Studies indicate that the amount of storage is highly variable. Westbrook et al. (2006), for example, recorded two dams on the upper Colorado River that inundated 5.8 and 12.0 ha of the nearby flood plain, primarily by diverting streamflow onto terraces downstream from the dams. However, working in eastern Washington, Scheffer (1938) recorded average pond storage to be 86 m^3 among 22 dams in one reach of Mission Creek; in that same study the author reported a single year-old dam on Ahtanum Creek stored 2,603 m^3 and that storage expanded to 6,170 m^3 the following summer. Because beaver colonies tend to build several dams, aggregate pond storage is often more meaningful than single dam storage capacity. Studies found a wide range of colony and dam density in the West. Clearly the amount of water stored in these systems is highly variable (Table 4).

TABLE 4.—Numbers of beaver dams, or beaver colonies, per kilometer of stream channel at various locations in high mountain environments of the western United States.

Authority	Location	Average number/km
Yeager and Hill (1954)	Southern Colorado	30 active and former dams
Butler and Malanson (1994)	Rocky Mountains (Montana)	25
Bates (1963)	Wasatch Range (Utah)	24
Smith (1980)	Wyoming	1.3
Busher et al. (1983)	Eastern Sierra Nevada	0.75 to 1.5 colonies

Dams also divert surface flows to slower hyporheic flows. However, due to the impermanence of extant dams and the unpredictability of new dams, related sub-surface flows are difficult to study and quantify. In Westbrook et al.'s (2006) study the team was able to quantify dam-related hyporheic storage lost. In that case, a monitoring station 670 meters below the failed dam indicated that within a week of the breech, water levels dropped from 21 cm above to 41 cm below ground surface. While the effect is clear, in order to calculate storage one must characterize local soil water-holding capacity. Other findings are less circumstantial and are more suggestive. Studying 10 dams on first order streams in low gradient glacial valleys in Glacier National Park, Meentenmeyer and Butler (1999) reported that three dams completely diverted all streamflow to aquifers.

Several other studies provide more definitive findings. Working on Bridge Creek in central Oregon, Lowry (1993) found that the riparian water table associated with a small beaver dam closely reflected pond surface levels laterally up to 50 meters from the pond, and estimated ground water storage at 90 m^3. Working on Currant Creek in a semi-arid area in southwestern Wyoming, Apple et al. (1985) studied the effects of re-introduced beaver. They found that within two years, seven beavers had created three dam complexes that raised adjacent water tables by 0.3 to 1.0 meters. Researching a 320 meter reach of Red Canyon Creek, a second order stream in the semi-arid Wind River Range of Wyoming, Lautz et al. (2006) found that about 30% of the stream volume entered hyporheic flows above beaver dams. Those flows raised water tables as far as 50 meters to one side of the stream. Water tables reflected pond surface levels and were maintained at 20–40 cm below the pond surface. The authors also reported that various portions of the study reach alternatively gained water and lost water to hyporheic flows depending on very local conditions confounding quantifications of streamflow.

Generally water storage both in ponds and in aquifers seems to be a function of a few key factors. Low valley gradient (with accordant low stream power) and broad valley floors both allow greater storage in dams and in aquifers (Pollock 2007). Sediment pore space and depth to impermeable substrate suggests reservoir capacity. Finally, the availability of woody dam-building material controls the size, efficacy, and permanence of dams. Thus, in California the most promising areas for water storage by beaver works probably rest among high meadows on headwater streams and amid side channels on lower elevation rivers.

Emmons (2011) estimated that should all currently incised meadows in the Sierra Nevada have their groundwater storage potential restored, about 80 million additional cubic meters of water would be cached. Some portion of that storage would transfer to the atmosphere through increased evapotranspiration (Hammersmark 2008, Hoffman et al. 2013). The increased flow is not significant statewide, but local habitat benefits might be.

Extending summer flows.—Evidence for augmentation of summer flows is perhaps the weakest aspect in the scientific research into potential benefits by beavers. Numerous review articles suggest that beaver dams and ponds augment low summer baseflows; however, studies relevant to California are largely anecdotal. Peer reviewed studies from the Pacific Northwest by Finley (1937) and Scheffer (1938) both reported significant decreases and increases in baseflow following beaver removal and re-colonization, respectively. However, neither study controlled for changes in precipitation nor land cover; further, Scheffer's (1938) results are not clearly confirmed by my analysis of relevant stream gauge records (see author forthcoming for further discussion).

As research into meadow hydrologies in California has found, it is very difficult to control all variables relevant to baseflow augmentation. Studies seeking to quantify the effects of beaver are confounded by multiple uncontrollable variables: they tend not to stay where they are released, making before and after studies nearly impossible; decadal scale climate trends, land use changes, topologies specific to study sites may also alter stream flow.

Plug-and-pond meadow restoration projects in upper reaches of the Feather River in northeastern California provide a potentially useful analog regarding potential modification of baseflows by beaver colonies. There, several stream reaches were re-directed to their former shallow, sinuous, non-incised channels, and the former channels converted to series of hyporheically connected ponds (Hoffman et al. 2010). Above-and-below seepage studies on several treated reaches indicated some aquifer absorption of high flows (Tague et al. 2008) and some augmentation of baseflows, but only into July (Cawley 2011, Hill et al. 2011). Several investigators reported that even where 48.3 ha of meadow were treated, base flow was not increased in August and September (Freeman 2010, Cawley 2011, Hoffman et al. 2013). Thus, widespread meadow restoration resulting from beaver activity may help blunt floods and increase stream flow in June and into July.

Sediment flows and storage.—Because dams decrease stream velocity, their associated ponds and overbank flows may allow sediment sequestration and accumulation (Westbrook et al. 2010). Several studies characterized the variability of sedimentation related to beaver works. In Yellowstone, Persico and Meyer (2009) reported that dams on small streams more effectively sequestered sediment. Butler and Malanson (1995) noted that low-gradient streams have lower suspended and bead loads, and so sedimentation rates also decrease. Studies agree that sediment accumulation decreases with pond age while volume increases with size (Table 5).

Some have argued that beaver-driven sediment accumulation may make significant changes in western landscapes. Working among headwater creeks in Colorado, Ives (1942:198) wrote that, "Detailed field studies indicate that water levels have been raised as much as two feet [0.6 meters], during the past 20 years, in about one-fifth of the beaver occupied area … As pond-filling proceeds at about the same rate as the elevation of water levels, but with the lag of several years, it may be assumed, from these figures, that valley floor elevation, as a result of beaver work, proceeds at a rate approximating one quarter inch per year." While the studies themselves were not included, Ives suggested that the "false senility" of streams—mature features such as meanders, oxbows, and peat bogs, all the result of low gradient—provide further evidence of valley-wide aggradation. Ives (1942) argued that beaver ponds normally transition to meadows following pond filling and that process repeats continually, as beavers move to new sites. Though somewhat anecdotal, this study is cited by 98 scholarly sources identified in Google Scholar's database.

TABLE 5.—Sediment accumulation rates, and volumes of sediment accumulated by younger and older, and smaller and larger beaver dams in Montana and Oregon, USA.

Authority	Location	Sedimentation Accumulation Rate (cm/yr) Younger <=> Older	Accumulated Volume of Sediment (m^3) Smaller <=> Larger
Butler and Malanson (1995)	Glacier NP Montana	27.9 <=> 2.1	
Meentenmeyer and Bulter (1999)	Glacier NP Montana	45 <=> 30	~ 9.4 <=> 267
Bigler et al. (2001)	Glacier NP Montana	43 <=> 19	
Pollock et al. (2007)	Bridge Ck Oregon	45 <=> 7.5	17 <=> 533
Westbrook et al. (2010)	Glacier NP Montana		Maximum of 750

In a more empirical study, Pollock et al. (2007) reported significant sediment deposition upstream from dams and argued that long-term occupation by beavers decreases bed slope and increases the area likely to be wetted during over-bank flows. Again, variability of landscape response to beaver activity is evidenced by the contrasting results of Meentenmeyer and Butler (1999), who reported that repeat field visits and aerial photo survey indicated that ponds seldom become meadows in Glacier National Park, Montana. Viers (2013) reported that where ponds do fill with sediment and transition to meadows, beaver works may provide important refugia for a host of native California species.

Nutrient flows and stocks.—As beaver works may slow and accumulate sediment, so too may they affect flows of nutrients. In their study of a 320 meter reach of Red Canyon Creek, a second order stream in the semi-arid Wind River Range of Wyoming, Lautz et al. (2006) reported that hyporheic exchange decreased total solute flow velocity by about 30%. Working on Currant Creek in southwestern Wyoming, Maret et al. (1987) reported that during high flows suspended solids, total phosphorous (but not ortho-phosphate), and nitrogen decreased in beaver ponds.

While decreases in suspended sediment are attributable to decreases in velocity, decreases in dissolved nutrients are due to adsorption to fine clays accumulated in the pond bottom sediments (Naiman and Melillo 1984). As a result, pond sediments tend to be very fertile. Naiman et al. (1994) measured available soil nitrogen in beaver meadows at 29.8 kg/ha compared to 6.8 kg/ha in a nearby dry forest. Other investigators reported that total organic carbon is also elevated in pond or meadow soils. Westbrook et al. (2010) analyzed the soil sequestered behind a failed dam and found relatively abundant nutrients: carbon was 24.1 g/kg of soil, total nitrogen 1.5 g/kg soil, and total phosphorous 0.9 g/kg soil (see also Klotz 1998). Naiman et al. (1986) reported that organic carbon turnover time in pond sediments was about 161 years, compared to 24 years for a nearby riffle, and that the pond's stream metabolism index of ecosystem efficiency was over five times higher for the pool than in the riffle.

Nutrient sequestration suggests that high meadows might serve as significant carbon sinks. Norton et al. (2014) suggested that southern Sierra Nevada wet meadows contain about 54.3 mg/ha of soil organic carbon, or about 12.3% of all such carbon sequestered in the Sierra Nevada. In addition, these rich soils encourage further carbon sequestration in new standing biomass.

Vegetation.—As Yeager and Hill (1954) observed under certain conditions, beavers may denude riparian vegetation and "scalp" top soils from pond edges and may also cultivate riparian deciduous and wetland herbaceous production. They may accomplish this through several processes. First, beavers increase water availability both spatially across valley bottoms through hyporheic flows, through overbank flows, and through canals excavated in order to more effectively move cut wood to the dams (Seton 1953), and temporally by providing water further into summer dry seasons. Apple et al. (1985) illustrated the effect upon riparian vegetation: three summers after beavers were re-introduced on Currant Creek in southwest Wyoming willow had colonized and grown up to 2.0 meters in height in spaces where water tables had been raised by beaver ponds to within 40 cm of the surface. In the downstream reach where aquifers were not charged by beaver ponds, willows had not recovered. On the Colorado Plateau in New Mexico, Trimble and Albert (2000:91) noted the addition of "extensive riparian habitat, especially willows" 6–14 years after re-introduction. Other authors reported that aspen, alder and cottonwood also responded well to the wetter habitats created by beavers (Ives 1942, Baker 2003).

The results of several studies suggest that willows and aspen live mutualistically with beavers. Working in Rocky Mountain National Park, Baker et al. (2005) simulated the effect of beaver browse on riparian willow with and without elk browsing. With elk herbivory, willows produced fewer and longer roots and displayed a higher percentage of dead biomass. Pruning followed by elk exclusion resulted in shorter, but far more numerous shoots; total stem biomass after three years was 10 times greater without elk browsing and those plants recovered 84% of their pre-cut biomass after only two growing seasons. With browsing by elk, however, plant biomass recovery was only 6%. Thus, under certain conditions, beavers may cultivate the development of bank stabilizing willow carrs, but only where elk browsing is limited. Because elk hunting licenses constitute an important revenue source for the California Department of Fish and Wildlife, reducing populations may require further budgetary support from the State. In Yellowstone, re-introduced wolf populations effectively moved elk away from streams and allowed both willow re-growth and subsequent re-occupation of streams by native beaver populations (Ripple and Larsen 2000).

Beavers may affect other changes in riparian forests. By taking down more mature trees, either through cutting or by drowning roots, and especially of conifers, beaver works may create light gaps that allow the growth of early successional species such as alder and willow, creating a diverse ecotone at the margin of their browsing zone 30–50 meters from the edge of their ponds (Donkor and Fryxell 2000). Several investigators noted that sedges and other wetland plants often colonized the saturated margin of beaver ponds (Johnston and Naiman 1987, Pollock et al. 1998, Westbrook et al. 2010). Clearing of riparian canopies may also result in problematically warmer stream temperatures.

Flood events.—Several review articles suggested that beaver works may attenuate flood events (e.g., Parker 1986). Hillman (1986) and Ehrman and Lamberti (1992) reported evidence of this in low-gradient landscapes. Working in mountainous northern Idaho, DeVries et al. (2012) documented the hydrological effects of anthropogenic structures that emulate beaver dams and found that check dams increased the frequency of overbank flows that worked to dissipate flood crests (see also DeBano and Heede 1987). Taking a different approach, Beedle (1991) modeled flood behavior amid glacially carved valleys on Kuiu Island in southeast Alaska. His model assumed that all dams were at capacity at the time of the flood, so that much of the attenuation resulted from deflection away from channels. He found that any one dam decreased flows by only about 5 percent, but that a series of five large dams reduced the peak flow of a two-year flood event by 14 percent, and reduced the peak of a 50-year event by four percent. These are small, but potentially meaningful, changes.

Beaver dam failures figure prominently in this literature. Working in a desert environment on the Bill Williams River in Arizona, Andersen and Shafroth (2010) reported that over 50 percent of beaver dams were damaged in a relatively large flood pulse of about $60 m^3$/sec, and that a pulse as low as 5 m^3/sec caused significant damage. On a 32-km reach of Bridge Creek in semi-arid central Oregon, Gibson and Olden (2014) reported over a period of 17 years that no dam persisted longer than 7 years and that most breeched within two years. However, in agreement with Demmer and Beschta's earlier study (2008), the authors found that these dams did attenuate high flows through their ability to divert high flows to local terraces and by creating greater sinuosity and valley bottom heterogeneity. In Glacier National Park, Westbrook et al. (2010) also reported that extant and breeched beaver dams increased riparian drainage complexity, and also increased vegetation capable of flood attenuation. Two groups of investigators added anchoring structures and noted that anchoring significantly increased dam durability (Apple et al. 1985, Pollock et al. 2012).

In some contexts, beaver-enhanced riparian vegetation may play an important role in flood mitigation. Smith (2007) offered an extensive study on the role and capacity of willow carrs to slow flood waters, and that is particularly relevant given the ability of beavers to cultivate these thickly branched willow stands. Those investigators reported that where stem spacing is less than 30 cm, vegetative stalks up to 2 meters in height, whether flexible or rigid, are able to reduce boundary shear stress to allow sediment deposition even if over-topped. In short, thick willow stands not only protect terraces from erosion, but also trap new sediment even during flood events. This vegetative aspect of beaver ecology could, thus, attenuate anticipated increased floods and sediment mobilization in California.

Changes in spring recession and ecotones.—As discussed above, for many plant, invertebrate, and aquatic species, the recession of high spring flows produces a vital, yet transient and moving, ecotone. The altered timing and decreased availability of these wetted margins promises to stress certain species of riparian plants and invertebrates. Both intact and broken beaver dams can create similar habitat. Breeched dams expose nutrient-rich and sometimes bare soils. Because beavers typically use soil to seal leaks in dams, the structures themselves may offer moist spaces available for colonization by invertebrates or plants, or by both. Mature dams often host willow, cottonwood, and aspen samplings, young trees whose roots can help to further consolidate dams (Bigler et al. 2001).

Wildfire.—Thus far few studies have been conducted into the relationship between beavers and wildfires. In his encyclopedic *Lives of Game Animals*, Seton (1953:455) wrote that "by conserving the water supply, the Beaver keeps little brooks running all year, instead of only freshets, so the forest is helped by irrigation. …Its ponds provide valuable fireguards." However, he did not offer evidence supporting these assertions.

More careful studies offer insights into beaver-wildfire interactions. Working in areas formerly covered by continental glaciers, two studies reported rather different interactions between beaver presence and fire. In Mount Desert Island, Maine, Little et al. (2012) used aerial surveys to assess beaver response to a fire in 1947 following beaver re-introduction in 1921. Following the fire, the researchers reported that dams increased rapidly in the burnt areas, but decreased from 60 to 10 in unburned areas by 1970. They also documented a decline in dams in the burned areas from about 100 in 1980 to fewer than 40 in 1990. Interestingly, ponds in this environment were observed to become meadows.

Hood et al. (2007), working in Elk Island National Park in Canada, studied beaver lodge occupation in relation to prescribed fires. They reported that lodges were nearly uniformly abandoned following first burns, and completely abandoned following subsequent fires; they also reported that if the area does not burn again over the following 20–30 years, pond creation increases. The authors suggested that trembling aspen (*Populus tremuloides*) regenerates well after fire. Bailey and Whitham (2002) reported that aspen regenerated 10 times more biomass following a severe burn. However, when elk are present, browsing decreased standing aspen biomass 90-fold, and so severely limited beaver re-colonization following fires.

Wildfires can also increase sediment mobilization that can be problematic for human and wild habitats. Once stripped of vegetative cover, slopes are exposed to sheet flow and gullying. Ice et al. (2004) reported that the potential for soil mobilization increased with the severity of fires. In very intense fires soil can become mineralized and nearly impermeable, forcing any runoff to flow rapidly down-slope, entraining soil particles along the way. Beaver dams may help sequester sediment in this context as well. Christian's (2014) comparative aerial surveys of eastern Glacier National Park found that prior to a large fire upstream pond sizes were variable year to year with changes of 40% typical. Following the fire, ponds steadily decreased in size, indicating sequestration of some portion of increased sediment flows.

As noted previously, wildfires will tend to increase stream temperatures. Beaver works, through increasing residence time in ponds and through decreasing shading gallery forest canopy, may also increase stream temperatures. Where stream temperatures are very cold, this may benefit certain native species; however, in many contexts this increase in stream temperatures may be problematic to salmonids. Dams can also work, however, to cool mid-summer stream temperatures when cold spring flows diverted to aquifers re-join streams 1–3 months later (Lowry and Beschta 1994). This retention and delayed release of cooler spring water might more generally buffer increasing summer stream temperatures.

Thus, following wildfires beaver dams may help sequester sediment, very locally decrease seasonal stream temperatures, and enhance riparian revegetation. However, the persistence of beaver colonies following wildfires seems highly variable and dependent in part, upon low elk abundance and subsequent browsing.

Discussion

Recent climate models forecast decreased snowpacks and summer streamflows, earlier and shorter spring spates, increased flood magnitudes, higher stream temperatures, and increased area of wildfire amid California's highlands—all with implications for habitat alteration. Few geographically analogous studies on beavers have been published, several of those original studies are somewhat anecdotal, and their claims apparently are at times exaggerated. However, several valid studies do suggest that on some of California's headwater streams beaver dams may work to recharge aquifers, augment baseflows for several weeks into summer dry seasons, sequester sediment and nutrients, encourage restoration of meadow vegetation and willow carrs that can ameliorate some of the problematic aspects of floods and wildfires, and supplement decreasing recessional riparian ecotones.

In short, beavers cannot mitigate all of the anticipated climate related changes in California's highland hydrologies. However, as this literature review suggests, beavers potentially offer meaningful local benefits. Unlike human-engineered projects, the effects of beavers on local hydrologies and habitats are variable and uncertain, and further investigations particular to California's highlands is warranted.

Extant studies suggest experimental designs to study hydrologies and habitat changes. As before and after studies are highly problematic due to subject mobility and variable boundary conditions, a simultaneous investigation of two analogous streams or watersheds, one with and one without beavers, would obviate problems posed by inter-annual precipitation and temperature variability and avoid re-introduction issues specific to California. Ideally, study meadows would not be connected to adjacent watersheds hyporheically, thus allowing accurate quantification of the effect of beaver works on timing of flows leaving the meadow. The stream reach seepage studies conducted amid the plug-and-pond meadow restoration projects on the Feather River offer an alternative design for studying water storage and baseflow augmentation. Such studies could align with on-going efforts to restore meadowlands in California. A nascent wetland restoration grant program funded through California's carbon market and administered by the California Department of Fish and Wildlife might prove a reliable source of financial support.

Several of the studies reviewed here indicate that the ecosystem services provided by beavers are increased as colony density increases on streams and in watersheds. The extent of additive benefit is not well quantified, but a controlled study of beaver re-introduction on a watershed scale is currently under way in the Methow Valley in eastern Washington. There, the Methow Conservancy project—a partnership between Washington Department of Ecology, Washington Department of Fish and Wildlife, The US Forest Service, and the Pacific Biodiversity Institute—is engaged in a watershed scale, before-and-after study of the hydrological, geomorphic, and ecological effects of beavers. They have installed 6 flow and 32 temperature stations to monitor changes. Their experimental design calls for a three-year pre-study period prior to beaver introduction and a 3–5 year post-introduction monitoring period. The protocol has been confounded by beavers not staying or succeeding in the pre-monitored release sites. As of 2013, introduced beavers had successfully inhabited only one-third to one-half of the 45 release sites. Results thus far are also confounded by environmental variability. The strength of findings will also be subject to changing boundary conditions (wetter, drier, warmer, cooler seasons) that may coincide with re-introductions and so confuse causation. The group plans to begin publication of results as early as 2018. Due to topography, results there may be most directly applicable to California's Cascade Range and coastal ranges.

Though able to create their preferred environment to a degree, beaver persistence requires low-gradient and wide stream plains. Even when well established, they apparently are also subject to long-term drought. Persico and Meyer (2009) found in Yellowstone

National Park that beaver have been endemic throughout the Holocene; however, during two notably dry periods, from 2200–1800 and from 950–750 years BP, beavers were absent from the area. Beavers may not be able to persist into California's drier future.

Finally, though advocates often portray beavers as a very low cost means of stream restoration or climate change mitigation because they tend to interact with built infrastructure, they also require management. Publications such as the Oregon Department of Fish and Wildlife's monograph detail techniques for live-management; that activity would require resources beyond the current budgets of many wildlife or public land management agencies, but holds the potential to provide benefits beyond costs.

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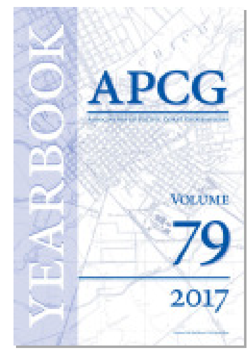

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Institutional Obstacles to Beaver Recolonization and Potential Climate Change Adaptation in Oregon, USA

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ABSTRACT

Across the American West, stream flows are becoming more seasonal. Climate models predict that this trend will intensify for the foreseeable future. As a result, moist habitats and human water sources are likely to be diminished in dry seasons while flows will intensify in wet seasons. Through their dam/pond systems, beaver have been shown to increase water storage in ponds and surrounding floodplains, thus slowing winter flows, increasing riparian and meadow water availability, and extending stream flow up to six weeks into dry summer seasons. Thus, allowing an increase in historically low beaver populations could provide a low-cost means of addressing both habitat and seasonality concerns. Yet, in Oregon, beaver are absent from the official discourses on adapting human systems and habitats to climate change. Through forty key informant interviews and an analysis of official policy and publications, this study identifies and critically examines five institutional blockages to beaver recolonization. That analysis clarifies the imprint of political pragmatism and institutional sub-cultures upon beaver presence in Oregon today.

Keywords: *beaver reintroduction, climate adaptation, institutional cultures, Oregon.*

Over the past decade in the Western United States, several nongovernment groups and individuals within government agencies have become interested in assisting beaver recolonization. These agents are motivated primarily by concerns with habitat restoration. Research in Oregon and Washington shows that beaver dam/pond systems can significantly enhance habitat for salmonids (Pollock with various co-authors: 2007, 2004, 2003; Burnett et al. 2007) and for fifty of the 115 species identified for special treatment by the Oregon Department of Fish and Wildlife (2006b; see also Müller-Schwarze and Sun 2003). Other actors are also interested in the ability of beaver to create wetland habitat as a way to moderate the predicted landscape-scale drying associated with climate change in the Western United States (Pollock et al. 2012; DeVries et al. 2012; Wild 2011; Bird et al. 2011).

Several studies indicate that the observed shift from winter snow toward rain regimes in the West's highlands will strengthen in the coming decades (Westerling 2016; Mote and Salathé 2010; Nolin and Daly 2006). Related studies forecast that currently increasing winter and decreasing summer stream flows will become ever more pronounced (Chang and Jung 2010; Chang and Jones 2010). Beaver could potentially mitigate against that seasonality in a number of ways (Baldwin 2015). In appropriate conditions, beaver can build up to ten dams per channel kilometer (Warren 1926; Baker and Hill 2003), and in low gradient environments with wide valley bottoms, each dam can bank up to 7,400 cubic meters of water in associated ponds and through local aquifer recharge (Westbrook, Cooper, and Baker 2006). One policy conservation specialist (Vickerman 2011) referred to beaver recolonization as "low hanging fruit"—an inexpensive program with tangible benefits.

Yet, in the official discourse of habitat restoration and climate change adaptation in Oregon, beaver are nearly absent; and across Oregon landscapes, there is little evidence of increased beaver presence. This study asks, "Why?"

In an effort to understand these policy and practical absences, this study examines and characterizes the culture of land and wildlife management professionals and policy makers in Oregon. Through forty key informant interviews and a critical review of literature published by state wildlife management and climate change institutions, the study identifies and critically analyzes five institutional obstacles to beaver recolonization and/or reintroduction. The first two of these are legislative: (1) the need for "political neutrality" in climate change adaptation documents and recommendations published by the state, and (2) the statutory listing and treatment of beaver as predators. The latter three pertain to positions shared by many wildlife management specialists that: (3) beaver currently occupy all appropriate habitat, (4) trapping does not affect populations or recolonization, and (5) beaver reintroduction is ineffective.

Historical Background

Our knowledge of current and historic beaver populations and presence in Oregon and in the West generally is incomplete (see Lanman et al. 2013 for review of pre-historic populations in California). Because beaver are not game animals, the Oregon Department of Fish and Wildlife (ODFW) has not conducted censuses of them.

Because most beaver populations were significantly reduced through commercial trapping prior to 1840, well before the General Land Office Surveys of the West, there is little historical record of beaver presence or effect on Oregon landscapes. Trapping company records give some indication of beaver populations and depredation. For example, between 1831 and 1834, Fort Vancouver received 405,472 pelts primarily from what is now northwestern Oregon and southwestern Washington (Kebbe 1960). Journals of early explorers and trappers describe how now-channelized and arid valley floors across the American West were once difficult to traverse due to multiple channels and broad riparian flood plains covered by dense vegetation. These were landscapes created and maintained in part by beaver (Ogden 1950; Pattie 1831; Work 1945; Seton 1929). On a continental scale, pre-trapping beaver populations are estimated to have been between sixty million and three hundred million (Butler and Malanson 2005; Naiman et al 1988). Today that population is estimated at three to six million, with most of them in Canada and Alaska (ibid.). Anecdotal evidence indicates that beaver populations in Oregon are significantly below pre-Euro-American contact levels. The state does not census beaver and no estimate of current populations is available.

Over the past 115 years, state and federal governments have vacillated between promoting and killing beaver. In 1899, the Oregon legislature empowered the Game Commission to enforce a new ban on trapping. Beaver populations increased as a result (Kebbe 1960). In 1918, the trapping ban was lifted and populations again declined. In 1932, the state re-instituted a ban on killing beaver on lands outside the agriculturally important Willamette Valley. At the same time, the United States Forest Service (USFS), Bureau of Biological Survey and the Oregon State Game Commissioner cooperated in live-trapping beaver where plentiful and reintroduced 962 beaver to areas where humans had extirpated beaver. From 1939 through 1945, the state reintroduced more than three thousand beaver, and populations increased notably (ibid., 4). In 1945 the program enlisted 590 primarily Willamette Valley landowners interested in hosting beaver on their property. By 1950 the number of participants had increased to 1,500. As an increasing number of farmers were learning to work with beaver, others advocated for increased efforts at extirpation. During the same period, the annual number of nuisance removals increased from 3,000 to 6,000 (ibid.). Unable to satisfy all requests for nuisance removals by live-trapping, the state again opened agricultural lands to limited trapping in 1951.

In the 1970s the idea that beaver could be useful in restoring riparian habitat again gained currency among certain public lands managers. Federal and state agencies closed several stream reaches to beaver trapping (ODFW 2010b). In most cases, those reaches are on lands managed by the Bureau of Land Management (BLM) and the USFS. The entire Mt. Hood and much of the Ochoco National Forests, for example, were and remain closed to licensed beaver trapping. In the 1990s the listing of symbolically and economically important salmon species as "endangered" spurred further study of beaver-fish interaction (Mitchell and Cunjak 2007). Several interviewees in the current study reported that fisheries biologists with the ODFW found that in the Oregon Coast Range, the single greatest impediment to coho salmon restoration was a lack of pools that provide refuge from high winter stream flows that flush juveniles to sea prematurely. The proposition that reintroduced beaver could again provide that ecosystem service is discussed widely among ODFW officers.

Today in Oregon, the "Beaver State," there is no consensus on beaver among the various groups charged with the management of public lands. This study finds that groups and individuals who are against increased beaver presence largely control public policy and its formation, and through legal institutions have made killing beaver largely legal and publicly invisible. The analysis then turns to interviews with professionals practically engaged with beaver management and identifies three cultural institutions that work against support of beaver recolonization in Oregon.

Methods

This paper is primarily an analysis of discourse, in the broad sense of the term, and includes extant literature, ongoing public discussion, legal, cultural, and political institutions, everyday operations by agents that affect beaver, and the understandings that guide management agendas and actions. The study employs three primary methods to gather information for analysis: (1) a review of thirteen state publications on climate change and adaptation, (2) the discourse and policy produced through meetings held in Oregon in December 2010 and February 2011 by the Oregon Watershed Enhancement Board, the Oregon Sustainability Board, and the Oregon Global Warming Commission, and (3), forty open-ended interviews with thirty-six key informants. Those informants included eight serving officers of the Oregon Department of Fish and Wildlife (biologists specializing in fish or in wildlife, stream restoration experts, and regional and agency managers). The study also included interviews with representatives of the USFS, the BLM, the Oregon State University Agricultural Extension Service, and the Oregon Climate Change Initiative. Interviews also included representatives from several non-government environmental organizations, including the Climate Leadership Initiative, the Beaver Advocacy Committee, the Defenders of Wildlife, and three watershed councils. Interviewees were selected for their roles as wildlife managers generally, and familiarity with beaver reintroduction and recolonization specifically. Interviews were conducted via telephone and in person from January to August of 2011.

As an inductive study, interviews were semi-structured. Questions addressed four themes: (1) informants' understanding of beaver in Oregon and their organization's position, (2) the basis of those understandings, (3) opinions regarding beaver reintroduction and recolonization, and (4) perceived problems with beaver reintroduction and recolonization. Discussions normally followed the informant's expertise and extended beyond these themes in ways unique to each interviewee.

I received considerable cooperation from interviewees. Perhaps because I have trained very broadly as a geographer of human-environment relations, interviewees seemed at ease discussing diverse matters from policy formation to geomorphic stream response and habitat restoration. As a native of the area, I could discuss places and issues of concern with a familiarity that may have encouraged interviewees to be forthcoming with detail and opinion. Respondents are treated confidentially, as information provided could affect professional relationships. Officers of the ODFW were especially generous with their time and candid in their responses—suggesting a relatively healthy intra-institutional environment.

Political Obstacles to Beaver Reintroduction

Obstacle #1: Political Neutrality

The publication of reports by the State of Oregon is a political process. In order to be published, reports must not raise objections from the legislators and lobbyists who approve and fund them. This need for what informants called "political neutrality" shapes reports on climate change in important ways.

Between 2008 and 2017, nine agencies and state-mandated workgroups published thirteen studies addressing climate change and wildlife and land adaptation (see Table 1). Reports such as these play a central role in state policy and practice. And even though the potential benefits of beaver re-colonization are both acknowledged in peer-reviewed (Hood and Bayley 2007; Collen and Gibson 2001) and grey literature (Bird et al. 2011; Wild 2011; Tippie 2010), there is no mention of beaver in any of these reports. This study sought to understand this absence through an analysis of the reports and the report writing and publication process.

Publishing Group	Title	Published
Oregon Climate Change Research Institute	*The Third Oregon Climate Assessment Report*	2017
Oregon Department of Fish and Wildlife	*Oregon Conservation Strategy*	2016
Department of Land Conservation and Development	*Strategic Plan 2014-2022*	2014
Oregon Water Resources Department	*Oregon's Integrated Water Resource Strategy*	2012
Oregon Global Warming Commission	*Report to the Legislature: 2011*	2011
	Interim roadmap to 2020	2010
Oregon Water Resource Commission	*Preparing Oregon's watersheds for climate change*	2010
	Prioritization framework: Improvement priorities at basin and watershed scales (draft)	2010
Adaptation Framework Work Group	*The Oregon climate change adaptation framework*	2010
Oregon Climate Change Research Institute	*Oregon climate assessment report*	2010
Department of Land Conservation and Development	*Climate ready communities: A strategy for adapting to impacts of climate change on the Oregon Coast*	2009
Oregon Climate Change Integration Group	*A framework for addressing climate change*	2008
Oregon Department of Fish and Wildlife	*Preparing Oregon's fish, wildlife, and habitats for future climate change: A guide for State adaptation efforts*	2008

Table 1.—Recent publications by State of Oregon agencies and workgroups reviewed for this section.

In Oregon's official response to climate change, two work groups are prominent. The Oregon Climate Change Research Institute (OCCRI), a collaborative group of more than eighty authors, leads efforts to characterize ongoing and expected effects of climate change. In its first full report (2010), OCCRI identified four key environmental changes: increases in temperature of about 0.2-1°F per decade, warmer and drier summers, some evidence of increased extreme winter precipitation events, and sea-level rise aggravated by greater wave heights during storm events. Each of these projected trends is already evident in environmental records.

The second group, the Adaptation Framework Work Group (AFWG), is charged with creating an institutional framework to guide and enable state agencies in their efforts to mitigate and adapt to climate change. The AFWG (2010) translated the four primary changes identified in the OCCRI report into eleven risks likely to affect Oregon landscapes in significant ways. Those risks and their relative probability of occurrence are listed in Table 2. Of the risks identified by the AFWG, numbers 2, 3, 5, 7, 8, 9, and 10 all result from an increased seasonality in hydrologic regimes. All are exacerbated by decreasing storage of water in landscapes in the form of snow. Though a literature addressing the ability of beaver to help adapt to these effects of climate change is newly emerging (see Bird et al. 2011; Wild 2011), knowledge of the role beaver play in decreasing hydrologic seasonality at local scales has circulated for some time (Naiman et al. 1988; Baker and Hill 2003). Yet, the in publications listed in Table 1, beaver are completely excluded from the texts; though a beaver is prominently pictured on page 5 of the ODFW's *Preparing Oregon's Fish, Wildlife, and Habitats for Future Climate Change* (2008).

The absence of any mention of beaver or beaver recolonization is part of a wider pattern revealed in an analysis of the reports. Generally, the reports avoid calls to make *any* material changes. Instead they recommend: increasing environmental monitoring, increasing education in public schools, identifying new funding sources for related programs, reviewing and developing state policy, and investing in building state agency capacity. The reports also call for increasing capacity for "adaptability" and/or "resilience," though the meanings of these terms are not elaborated, except to suggest greater empowerment of local-scale agencies and projects.

The document that comes closest to specific calls to action is the ODFW's *Preparing Oregon's Fish, Wildlife, and Habitats for Future Climate Change* (2008). There, the agency recommends investing in implementation of the *Oregon Conservation Strategy* (2006b), a far-sighted document directing the ODFW to address critical issues, including threatened species. My review of that document suggests that more beaver ponds could benefit eleven of the sixty-two birds, two of the five reptiles, seventeen of the eighteen amphibians, and twenty of the thirty fish species listed for special treatment (compiled from pages 320–349). And even though every ODFW officer interviewed for this study had a well-defined opinion regarding beaver, the animal is completely excluded from the report.

Rank	Risk	Likelihood	Beaver mitigation
1	Increase in average annual air temperature and likelihood of extreme heat events	Very likely	
2	Changes in hydrology and water supply; reduced snowpack and water availability in some basins; changes in water quality and timing of water availability	Very likely	Direct
3	Increase in wildfire frequency and intensity	Likely	Indirect
4	Increase in ocean temperatures with potential for changes in ocean chemistry and increased ocean acidification	Likely	
5	Increased incidence of drought	Likely	Direct
6	Increased coastal erosion and risk of inundation from increasing sea levels and increasing wave heights and storm surges	Likely	
7	Changes in abundance and geographical distributions of plant species and habitats for aquatic and terrestrial wildlife	Likely	Indirect
8	Increase in diseases, invasive species and insect, animal and plant pests	Likely	Indirect
9	Loss of wetland ecosystems and services	Likely	Direct
10	Increase incidence and magnitude of damaging floods and frequency of extreme precipitation events frequency of extreme precipitation events	More likely than not	Direct
11	Increased incidence of landslides	More likely than not	D23

Table 2.—Ranked list of likely risks posed by climate change in Oregon (AFWG 2010, 5).

In order to understand this absence, I attended three state board meetings. I interviewed six board members; several of these explained independently that report acceptance and publication is a primary goal of boards. Several respondents also related that because reports must be approved by legislative committees, they must not include content that might raise objections from variously interested politicians. Informants referred to this quality as "political neutrality." Several board members indicated that the boards concerned were particularly "risk averse," i.e., concerned with continued funding and conscious of the need for political neutrality. Interviewees also reported that, as a result, reports are also somewhat "'action neutral."

Responses regarding beaver specifically were consistent with this wider pattern. At meetings of the Oregon Watershed Enhancement Board and a joint meeting of the Oregon Sustainability Board and the Oregon Global Warming Commission, two board members and one agency expert independently indicated that there has been informal consideration of using beaver to mitigate wetland loss. Due to the low cost of beaver recolonization, informants characterized it as especially attractive, given the currently constrained financial capacity of state agencies. At another meeting, two board members commented that representatives from the Department of Agriculture (DOAg) have, on several occasions, expressed "strenuous objection" to including any language suggesting that beaver should be encouraged as a strategy to mitigate or adapt to the effects of climate change. Thus, beaver are not politically neutral; their inclusion threatens the acceptance and publication of agency reports representing weeks and months of effort.

Obstacle #2: The Statutory Classification of Beaver as Predators

In Oregon, two bodies of law regulate beaver taking. The ODFW defines beaver as fur-bearing animals and regulates trapping accordingly. Under that regime, all beaver taking must be licensed. In order to obtain a license, the ODFW requires that applicants take a course on allowable practices, and at the end of each season, trappers must submit a harvest report card in order to obtain a license in subsequent years. Under the ODFW regime, property owners are required to file for a damage permit before they may legally kill a beaver on their land. Thus, the ODFW has the ability to regulate and accurately track human taking of beaver (ODFW 2010b). My analysis

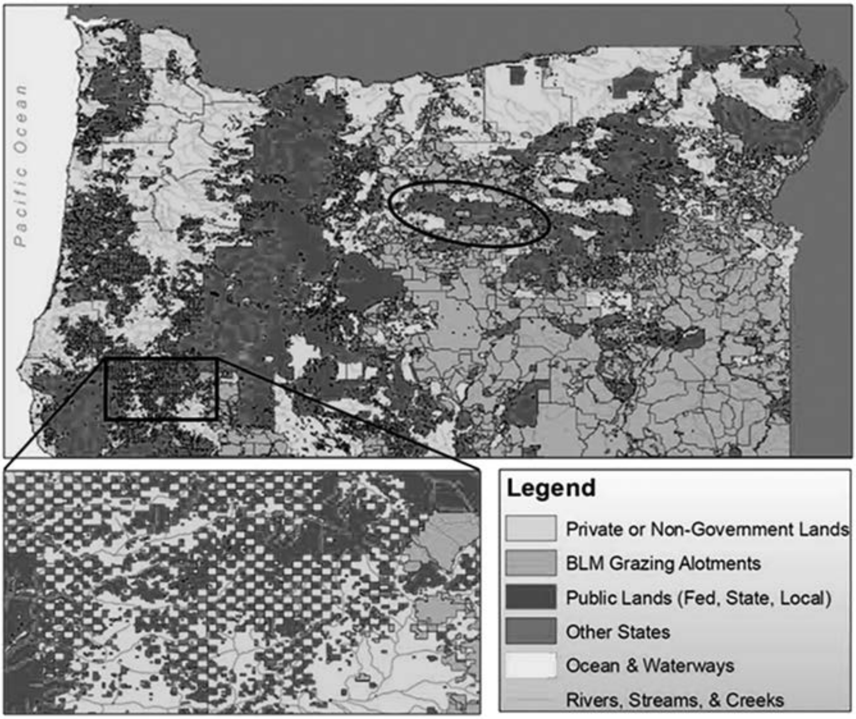

Figure 1.—Mapping human predation regimes in Oregon. Oregon statutes allow unregulated beaver predation on all private and leased public lands. Trapping is regulated by permit only on non-leased public lands. The oval indicates where Ochoco National Forest is. Inset map illustrates range fragmentation in terms of predation regime.

of data provided by the ODFW indicates that from 1998 to 2010, the mean average annual trapping take was 2,971 beaver.

However, under the advocacy of the Oregon Department of Agriculture (DOAg), a second body of law has also been applied to beaver "control." Oregon Statute 610.002 defines predatory animals as "feral swine …, coyotes, rabbits, rodents [beaver] and birds that are or may be destructive to agricultural crops, products and activities, but excluding game birds and other birds determined by the State Fish and Wildlife Commission to be in need of protection. [1959]." The statute enables land holders to remove such animals at their discretion. The ODFW asked the Oregon Department of Justice (DOJ) for clarification regarding the two regulatory regimes. The DOJ opinion found no conflict in these two regimes in relation to the Endangered Species Act, and so let the statutes stand (Arnold 1984).

It is important to note that the Oregon DOAg also represents the timber industry. Long the center of the Oregon economy, logging companies have invested many tens of millions of dollars in extensive road networks with thousands of stream contacts. Because beaver may block road culverts or otherwise incorporate road grades in their dam projects, beaver activity can lead to road failure. Thus, the industry has significant interests in the right to "control" beaver on its lands. About forty-five percent of the state is privately owned, and so falls under this statute.

As Figure 1 illustrates, the area under the "beaver as predator" regime is significantly expanded by ORS 610.105. That statute states, "Any person owning, leasing, occupying, possessing or having charge of or dominion over any land, place, building, structure, wharf, pier or dock" may "immediately and continue in good faith to control" any listed predator. About thirty percent of Oregon lands are public lands held in lease, primarily by grazing and logging operators. Thus, across seventy-five percent of Oregon lands, beaver may be killed without record or regulation.

Further, the Predator Statute also forbids all state agencies from requesting any information regarding killing of listed animals. As a result, all evidence of beaver extirpation under the Predator Statute can only be anecdotal, and therefore may be dismissed as such.

Institutional Obstacles within the ODFW

Through interviews, the officers of the ODFW and several other experts expressed considerable difference in their understandings of and opinions about beaver in Oregon. In the following discussion, I identify three commonly held positions that work against beaver recolonization and reintroduction. After describing each, I critically analyze the discourse supporting these positions.

Obstacle #3: The Position that Human Predation Does not Decrease Populations

Within the ODFW, officers hold a wide range of positions regarding the effect of human predation on beaver populations. Many interviewees, both within and especially from outside the ODFW, believe that human predation inhibits beaver presence and recolonization. Five ODFW officers reported that they understood that fisheries specialists in particular felt that beaver taking was problematic. Alternatively, four officers disagreed for a variety of reasons.

Notably, few people trap beaver by permit in Oregon. From 2000 to 2009, the number of licensed trappers averaged 184. Two interviewees indicated that this contingency, though small, had been "very effectively" represented in the legislature through the Oregon Trappers Association (OTA), and that the OTA maintains close ties with Oregon's still powerful logging industry. Two interviewees stated that in early 2011, the ODFW was working to rebuild apparently strained relations with the OTA, explicitly including the association in trapping policy discussions. Several of the interviewees also characterized beaver trappers as good stewards of beaver populations, indicating their understanding that beaver populations need to be actively checked.

More importantly, these reported trappings do not reflect "removal" under the predator statute, as discussed above. Anecdotal evidence from a number of sources indicating that beaver extirpation is ongoing was supported by a public statement from a JWTR Timber Company spokesperson (KWP 2011). Even though JWTR owns 950 square miles of forestland, (approximately sixteen percent of Klamath County, and much of that county's forested area), their spokesman stated that they have had only one nuisance beaver on their land (time period was unspecified), they have fewer beaver than in surrounding National Forest lands, and that he did not know why there were not more. He also stated that people were removing beaver without explicit permission of JWTR, thus acknowledging their tacit approval of the practice. Needham and Morzillo's study provides further indirect evidence of beaver killing. It found that twenty-four percent of rural respondents indicated that they "do not want beaver on my property or on my neighbors' property," and twelve percent have either contracted to have beaver killed or done so themselves (2011, 17). Confirming this result, residents attending a related workshop in Chiloquin, adjacent to JWTR lands, reported frequent encounters with beaver carcasses marked by bullet wounds.

Thus, there are indications that human predation may significantly decrease beaver presence. The Predator Statute prohibits research into the scale of non-permitted taking.

Obstacle #4: The Position that Current Range is Appropriate and Maximal

Several of the ODFW officers interviewed asserted that beaver already occupy their appropriate range, and therefore efforts to allow or encourage range expansion are inappropriate. Much of what follows in this subsection is an analysis of the origins and accuracy of these assertions.

Interviewees offered several lines of evidence to support this claim. The most common argument offered against further efforts to expand beaver range—and this was offered in a very matter-of-fact manner, independently by three Wildlife Division officers—is that where there have been trapping closures, in some areas for up to forty years, beaver populations have not increased. The consensus within this subculture is that if the habitat is appropriate, beaver are already there. Several interviewees added that there is good connectivity along stream reaches, and that when two-year-old beaver leave the family, they often establish new pond systems; thus, populations are believed to be diffusing normally. Several interviewees also referred to an internal study that concluded that beaver populations were never great in Oregon.

The following discussion identifies four counters to these assertions. First, as noted above, the ODFW does not census beaver and has no data on populations, so statements regarding populations and range are not drawn from quantitative analysis. Second, as an ODFW wildlife biologist who has studied beaver relocation in the Cascade Range suggested, it is unknown how far beaver will travel to find good habitat, or what constitutes friction in that search. He has radio tracked a newly released beaver travelling up to eight miles in one night. However, that occurred immediately after a release, and travel was downstream, while recolonization is often a more difficult upstream journey.

A third counterpoint echoes the second. In support of the earlier assertion, several interviewees referred to the paucity of beaver in the Ochoco National Forest (ONF), even though trapping has been suspended for decades. However, as Figure 1 indicates, the ONF is essentially an island surrounded by private and leased public lands, where beaver may be killed without license or record. Further, while trapping has been suspended, "removal" under the Predator Statute has remained very much in place upon any leased land, up to 95.6 percent of the 344,000 ha forest. Additionally, as the inset map in Figure 1 illustrates, streams across much of Oregon seldom offer continuous conduits that are safe from human predation. Risk of animal predation during migration has also increased over the past thirty years as predator populations have rebounded (ODFW 2006a). A beaver without a den to shelter in during daylight hours is very easy prey for cougar, coyote, and bear. Thus, assertions of effective habitat connectivity are problematic.

A fourth counter regards the understanding that, based upon historic accounts, contemporary beaver populations in Oregon's Coast Range resemble pre-contact levels. Without exception, each of the four interviewees who made this assertion referred to an internal report by R. E. Rainbolt (1999), which concluded that historically "Beavers were *common* in the Coast Range, but not *abundant*" (ibid., 12, emphasis in original, terms not defined).

There are several exceptions to the Rainbolt report. First, most of the primary sources cited pertain to the estuary of the Columbia River. The report notes that there, both Captain Gray in 1792 and Lewis and Clark in 1805 (Lewis 1903) wrote that local peoples traded beaver pelts and on occasion produced several hundred pelts for trade. Lacking any "record or estimate of historic beaver populations in the Coast Range" (ibid,. 3), Rainbolt reviewed logs recorded by expeditions dispatched by the Hudson Bay Company to the "Coast Range." In fact, the 1826 expedition featured in the report did not venture beyond coastal estuaries, "due to channel obstruction by woody debris" (Davies in ibid., 5). According to Davies' log, natives along the central coast reported that "in the interior there were plenty" (ibid.) of beaver, and the expedition reported seeing many "beaver vestiges." Further south, on the Rogue River, the same expedition reported signs of beaver on every stream.

In further support of his assertion that beaver were not abundant, Rainbolt cites several sources that suggest that in the 1820s, local peoples, even in the Columbia estuary, were disinterested in hunting beaver. He concludes from this that either the local people were very "indolent" and/or that beaver were not plentiful enough to support a native trapping economy (ibid., 7–8).

However, Rainbolt fails to consider that those native peoples were suffering a demographic collapse as a result of exposures to European diseases. Boyd (1999) reports that by 1801 the Chinook, Tillamook, Alsean, Siuslawan, Coosan, and Tututni peoples had all suffered at least one smallpox epidemic, and in 1824 the groups at the north and south end of this range were known to have suffered an additional smallpox/measles epidemic. As a result, a pre-contact native coastal population estimated at about 11,300 people was reduced to 1,030 individuals at the time of treaty signings between 1853 and

1874. This could certainly explain the observed lack of interest in trapping among native peoples.

One additional point bears explication. In a 1988 review of this same historic literature, Guthrie and Sedell concluded that beaver were *plentiful* in the coast range in the first half of the nineteenth century. The authors highlight a 1854 account of traversing a slough near the Coquille River on the central coast. There, Esther Lockhart reported that boatmen had to stop at least every few hundred feet to break a beaver dam to allow the boat to pass, and that the dams would be back in place the next day. The authors suggest that the Coast Range was not heavily trapped because the mountain men of the time eschewed the soaking rains of Oregon's Coast Range.

Though it may seem a fine distinction, *plentiful* and *common* have very different meanings. *Common* implies present, as beaver are today. *Plentiful* connotes so many as to be easily gotten. By attending to Rainbolt's interpretation, and dismissing Guthrie and Sedell's, wildlife officers support a no-management policy, which is consistent with their institutional capacity. The ODFW does not have the financial resources to live-manage beaver. Interestingly, the Guthrie and Sedell study has been effectively excluded from institutional memory; none of the interviewees mentioned the study.

Obstacle #5: The Position that Reintroduction Is Ineffective

A majority of interviewed ODFW officers suggested that beaver reintroduction is ineffective—this despite the notable success of the state's reintroduction efforts in the l940s discussed above. Several officers referred to a pilot reintroduction effort sponsored in part by the Beaver Workgroup (an association of interested parties organized by the ODFW). An ODFW field biologist closely involved with the project reported that thirty-four adult beaver were live-trapped along the lower reaches of the Umpqua River, fitted with radio transmitters, and released at thirteen sites along three reaches of tributaries to the Umpqua River. Seventeen of the transplants are known to have died: nine by predation, four by vehicle collision, and four through other accidents. Of the remaining, ten transmitters have either fallen off or are no longer being tracked. Seven adults were still being tracked at the time of the interview. From this, one may reach two very different conclusions: a focus on confirmed living beaver yields a survival rate of twenty-one percent, while a focus on confirmed dead implies a survival rate of up to fifty-three percent. None of the officers referring to the program cited the latter figure.

The Beaver Workgroup has made efforts to increase the efficacy of beaver reintroduction. The Department has published a protocol for beaver reintroduction (2010a), and now maintains a Web page on live management. The biologist in charge of the Umpqua relocation project reported that much was learned and that subsequent projects could have a better success rate. The nongovernmental Beaver Advocacy Committee, led by Stanley Petrowski and Leonard and Lois Houston from the South Umpqua River, has had better success in relocation efforts in the same watershed, and is critical of the slow pace of the Beaver Workgroup. They assert that much of the Workgroup's research agenda has already been explored and is in the literature. In response, one ODFW officer suggested that those studies are often not particular to Oregon. Because the ODFW is responsible for any problems caused by relocation, caution on their part is understandable.

And, as one board member explained, historically, rural lawmakers' reactions to constituent complaints about beaver damage can be "swift and violent."

Discussion: Where to Go from Here?

Beaver recolonization faces a number of obstacles. Very real environmental obstacles inhibit beaver recolonization and reintroduction in Oregon. Several interviewees indicated that habitat conditions across much of their former range are unsuitable, following decades of vegetative denudation, stream channelization, and removal of large woody debris—all leading to more-rapid drainage and dam-destroying increases in stream power. Interviewees indicated that the cost of preparing a site for successful reintroduction can be quite high.

The institutional obstacles identified here also pose obstacles to beaver recolonization and reintroduction. However, as discursive constructs, these may be moderated through education. The need for political neutrality in committee reports might be blunted by changing the public's perception of beaver. Needham and Morzillo's (2011) study—published by ODFW—found that fifty-seven percent of rural landowners surveyed expressed interest in having beaver live on or near their property. The study also found that twenty-four percent of rural respondents did not want beaver nearby. Pro-beaver activists, such as Heidi Perryman of Worth a Dam in Martinez, California, have found success in changing anti-beaver attitudes through public education, particularly with children. Whether timber-land managers and others at risk of damage from beaver will be willing to voluntarily engage in damage mediation measures also seems questionable.

Nearly all interviewees who mentioned the statutory classification of beaver as predators also stated their belief that the designation has diminished beaver populations. Those interested in increasing beaver presence felt that de-listing beaver as predators would lead to significantly higher beaver populations. Although the ODFW could appeal the original DOJ opinion, consistent with ORS 610.002, the department might also move administratively to define beaver as "in need of protection," thus effectively de-listing them. Before any of these alternatives can be effective, the state will have to build institutional capacity to manage beaver populations and limit damage to roads. Oregon State University's Agricultural Extension Service, for example, is charged generally with educating rural landowners; however, that agency has only one wildlife specialist for the entire state (Sanchez 2011). Several ODFW officers similarly stated that the department does not currently have the human resources to respond to beaver nuisance complaints.

Reintroduction poses its own problems. Though many of the particulars of keeping beaver alive through the trapping and transportation process have been addressed (e.g., Tippie 2010; ODFW 2011), release site selection remains an issue. Wildlife managers have promoted the use of habitat suitability indices (or models) to identify optimum release sites (see Buckley et al. 2011; Wild 2011). However, those models are problematic in their assumption that beaver presence and absence are reliable indicators of habitat quality (Baldwin 2013). In so doing, they overlook the role of human predation in creating absence and so may mischaracterize habitat preferences and suitability (Carpenedo 2011).

Conclusions

While the policies and practices of wildlife- and land-managing institutions are, to an extent, science-based, they are also socially and culturally influenced. In an effort to understand the ways various institutions in Oregon have either failed to promote and/or have actively worked to inhibit beaver recolonization and reintroduction, inductive interviews with relevant experts and other agents provide certain insights. This study identifies specific cultural forms among wildlife and lands managers that work against allowing beaver recolonization and support the dismissal of possibility, and several of these beliefs are not well-founded. From a political economy perspective, powerful agricultural interests drive the need for political neutrality among state agencies and have worked to make beaver killing very possible and nearly invisible.

Evidence suggests that beaver could help human and non-human communities adapt to ongoing and projected effects of climate change in the Pacific West (see Baldwin 2015), and do so at relatively low cost. Whole critical literatures address why enlisting non-human beings is philosophically difficult (e.g., Plumwood 2002; and Baldwin 2016, 2006). Pragmatically, as keystone species, beaver produce their own spatial architectures that may conflict with land-owners' and -managers' intentions. On the other hand, beaver can also be managed in nonlethal ways to work cooperatively with land managers interested in cultivating a moister, and so a livelier, landscape in the face of anthropogenic climate change (Lundquist and Doleman 2016; Pollock et al. 2007; OWIC 1993).

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