Progress in Physical Geography
2015, Vol. 39(5) 576–593

DOI: 10.1177/0309133314567582
ppg.sagepub.com

The Coyote-Proof Pasture Experiment: How fences replaced predators and labor on US rangelands

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Abstract

Few scientific experiments have influenced more land than one conducted in the Wallowa Mountains of eastern Oregon by the US Department of Agriculture's Bureau of Plant Industry and US Forest Service in 1907–1909. Four square miles of land were enclosed with a "coyote-proof fence," guarded by a hunter, and stocked with an untended band of sheep. Data were collected on vegetation and sheep performance inside and outside the fence, and two years later success was declared. By 1910, the Forest Service had wrested range research from the Bureau of Plant Industry, subordinating the emerging field to timber production and fire suppression for decades to come. The young scientist who conducted the experiment, James Jardine, was promoted to Inspector of Grazing for the fledgling Forest Service, while his Wallowa collaborator, Arthur Sampson, went on to become "the father" of range science. The model of range management that they pioneered was applied across the US West and, later, on many rangelands in the developing world. Fencing and predator control are now generally viewed as unrelated management practices, but in the Forest Service model they were intimately connected. A critical physical geography of the Wallowa experiment reveals that the institutional context in which it occurred was more important than the findings themselves, and that although the results appeared to be scientifically rigorous and ecological, the methods were weak and the real criteria for "success" were economic. The high costs of fencing could be justified only if they were offset by a reduction in labor costs for herders. But without herders to guard the livestock, predators would have to be eliminated. Enormous public subsidies were required to implement the model, which continues to affect rangelands around the world.

Keywords

range science, grazing, predators, US Forest Service, fencing, herding, fire suppression

I Introduction

Lave et al. (2013) have proposed the name "critical physical geography" (CPG) for research that "combines critical attention to power relations with deep knowledge of biophysical science or technology in the service of social and environmental transformation." Such work neither oversimplifies physical geography as "naively positivist" nor seeks to criticize physical geography from the outside. Rather, CPG "requires critical human geographers to engage substantively with the physical

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sciences and the importance of the material environment in shaping social relations, while expanding physical geographers' exposure to and understanding of the power relations and human practices that shape physical systems and their own research practices.'' The need for CPG, they argue, arises both from the ubiquity of human influences on biophysical processes—reflected in the increasing adoption of the term ''Anthropocene''—and from the insight that scientific concepts and ideas are socially mediated or ''co-produced'' with the landscapes they seek to describe and understand.

At the core of CPG lies a ''reflexive and integrative epistemological spirit'' that strives ''to produce critical biophysical and social explanations while also reflecting on the conditions under which those explanations are produced.'' CPG thus involves scrutinizing not only the findings but also the concepts and categories of physical geography. These concepts and categories must be understood, moreover, *both* in terms of their theoretical origins within a discipline *and* in relation to the broader social and institutional contexts of their production. Scientific categories have histories; they should not be taken for granted as given or natural, but understood as the result of actions taken by particular people (scientists and non-scientists) in particular contexts. This is especially important in cases where repeated use over time has cemented concepts into the literature and occluded the decisions and assumptions that attended them at the outset. Such decisions necessarily reflected, in some measure, the social conditions in which they were made, and they very likely rested on assumptions that may have been faulty from the start, or that may have become faulty as conditions subsequently changed.

Critical understanding of the history of concepts and categories used by physical geographers (and biophysical scientists in general) is not the only task of CPG—the larger goal is to address contemporary problems and issues more effectively—but it is a necessary part of CPG insofar as the concepts and categories used today may benefit from a critical examination of their origins and histories. Elsewhere I have treated the terms ''carrying capacity'' (Sayre, 2008) and ''anthropogenic'' (Sayre, 2012) in this spirit.

This paper explores the origins of key concepts and practices in range science, a field of applied ecology that arose in the United States around the turn of the 20th century. The history of the discipline has received remarkably little attention from scholars, even within range science; critical scrutiny of it along the lines of CPG is virtually non-existent.[1] Prompted by concern that uncontrolled livestock grazing was degrading western public lands, federal government agencies tasked scientists to find the causes of degradation and devise ways to reverse it. What emerged was a set of ideas about how livestock, herders, herding dogs, and wild predators interacted to impact vegetation for better or worse, and a corresponding set of practices that were subsequently implemented across the West's vast public rangelands: fencing, regulated stocking rates, and predator control. In the century since this model was born, the connection between predator control and fencing has become invisible; the history told here allows us to see that rangeland policies might usefully be reconsidered in light of this lost connection. It also uncovers a key assumption of the logic behind the model—namely, that reduced labor costs would offset the costs of fencing—and it reveals a historical contingency that went on to have profound implications for western rangelands: the subordination of range science to timber production and therefore fire suppression.

II The Coyote-Proof Pasture Experiment

On May 9, 1907, the famous naturalist and Chief of the US Department of Agriculture's

Bureau of Biological Survey, C Hart Merriam, sent a short memo to Gifford Pinchot, head of another USDA agency, the recently created US Forest Service. “Dear Mr. Pinchot: Your proposition to build a wolf and coyote proof fence on the Imnaha National Forest in Oregon is of great interest to us, and the Biological Survey will gladly cooperate with the Forest Service in any way possible to secure satisfactory results.”[2] Three sentences later, Merriam—who in his career described more than 600 species of mammals—concluded with a blunt recommendation: “After the fence is completed, all wolves, coyotes, mountain lions and wild cats should of course be killed or driven out before the sheep are brought in.”[3] He made no mention of the purpose of the project, and his own agency’s involvement was quite limited.[4] But Merriam took an interest because the project was a scientific experiment, for which the fence was an important (and expensive) apparatus.

The Coyote-Proof Pasture Experiment was a joint effort between the Forest Service and a third USDA agency, the Bureau of Plant Industry (BPI). Conceived by Pinchot, it was designed by Frederick Coville, Chief Botanist in the BPI, and although it was not the first scientific experiment in range management, as is sometimes claimed,[5] it was the first to be deemed successful, and its results helped transform the very institutions that had produced it. Inspired by this perceived success, the Forest Service permanently took over range research from the BPI in 1910, and the young scientist whom Coville had hired to conduct the experiment, James T Jardine, became Inspector of Grazing for the Forest Service. Jardine’s collaborator, Arthur Sampson, went on to become “the father of range science.” The Wallowa experiment thus had enormous implications for how rangelands would be studied and managed for the rest of the 20th century. From four square miles in the mountains of eastern Oregon, a model of range management based on fencing and predator control spread across the rangelands of the western US in a matter of decades. In the second half of the century, the model was exported to the developing world.

Fenced pastures and the near-total absence of large predators have by now been ubiquitous on US rangelands for so long that they are widely taken for granted. “Open range” no longer signifies the absence of fences altogether, but instead their absence along remote roadways, where livestock may imperil motorists without the livestock owner being liable for damages. Coyotes, brown bears, and mountain lions persist throughout the West, and wolves and grizzly bears are still found in parts of the northern Rockies, but their numbers are too small to pose a significant threat to livestock; less than 0.25 percent of US cattle, for example, are lost to predators, including dogs.[6] Range fences are not even designed to repel predators, because doing so would be far too expensive relative to the small risks of predation. Today, fencing and predator control are treated as separate issues in public debate and policy recommendations,[7] and the historical link between them is forgotten.

To be sure, both fencing and predator control predated the Coyote-Proof Pasture Experiment, and their combined use on rangelands might be considered coincidental. But Coville and Jardine’s experiment united them in an effort to understand range livestock production *scientifically* and to use that understanding in the formulation of policies. The inspiration for the experiment lay not in rangelands at all, but in the much smaller pastures of the eastern United States and Europe, where fencing was primarily a means of keeping livestock away from crops, rather than keeping predators away from livestock. To apply the pasture model to the much drier, expansive lands of the western range, however, the Forest Service had to interpret the results of the Wallowa experiment in ways that elided or overlooked many important details. Fencing had to make sense at the scale of thousands or tens of thousands of acres, for example, rather than 1–40 acres. The results with sheep had to be extended to cattle, even though cattle are far less vulnerable to predation. Most importantly, the attribution of causality had to shift from the removal of predators—which putatively reduced livestock trampling of vegetation—to the control of stocking rates by fencing, which came to be viewed as improving the composition and production of range vegetation.[8]

The Coyote-Proof Pasture Experiment sanctioned and catalyzed the institutionalization of a set of practices of US rangeland administration and management that presupposed the combination of fencing and predator control. The model rested on weak scientific foundations, as we will see, but it spread for other reasons, enabled by large public subsidies over many decades, especially in the form of labor under Depression-era jobs programs. This is ironic because reducing labor—in the form of herders—was the semi-visible, ulterior motive of both fencing and predator control.

I The context: the USDA and the western range circa 1900

The first two decades of the 20th century were a period of ongoing and sweeping reorganization within the USDA, especially with regard to the West's vast public lands. At the turn of the century, the public lands resided within the Interior Department's General Land Office, whose principal mandate was to dispose of them under the nation's various settlement acts. But the Forest Reserve Act of 1891 had authorized the President to withdraw timbered lands from disposal, and as the forest reserves grew in size and number, Congress and the Interior Department scrambled to decide how to administer and manage them. Along with mineral resources and water, the region's key natural resources were forests and rangelands, both of which were considered to be in crisis due to unrestrained commercial exploitation. The forest reserves were justified legally as a means to protect timber and watersheds, but they also encompassed large areas where livestock owners had been grazing their animals for decades or more. The relationship between forests and rangelands, trees and grasses, timber and forage, was at once a scientific, management, and bureaucratic question.

Forestry had by this time emerged as a small but recognized scientific field, imported from Europe and first institutionalized at Cornell University in 1898 and at Yale in 1900. The USDA had begun assessments of the nation's forests in 1876, organized since 1881 under the Division of Forestry, and Division Chief Bernhard Fernow could point to thousands of pages of published forestry research when he stepped down in 1898 (Steen, 1998: 4). Research on rangelands, in comparison, had barely begun. It had not attracted the agency's attention until 1895, when the Division of Agrostology was created in response to devastating drought and consequent overgrazing, especially in the Southwest. Little more than taxonomic and reconnaissance surveys had been completed in the West by 1900 (Shear, 1901), when Agrostology was combined with five other divisions into the Office of Plant Industry, renamed the following year as the Bureau of Plant Industry. The Division of Forestry also became a bureau in 1901.

Without a land base, however, none of the USDA's various bureaus "could do more than advise and research" (Pyne, 1982: 191). Congress and the Interior Department had been studying and debating the administration of the forest reserves since their inception, but the matter was only resolved in 1905, when the reserves were transferred to the USDA and its new US Forest Service, headed by Pinchot and facilitated by his close friendship with President Theodore Roosevelt. As Pyne (1982) notes, the Transfer Act catapulted forestry to the forefront of American conservation not on the basis of its scientific credentials—which were quite meager in comparison to, for example, the US Geological Survey—but by virtue of the 63 million acres of land that the Forest Service suddenly controlled. Dedicated to science as the means of striking an optimal balance between utilization and conservation, Pinchot moved quickly to expand and consolidate research on several fronts. But the bureaucratic divisions within USDA persisted, and expertise on rangelands—what little there was of it—remained in the BPI.

The European forestry model was ill suited to North American forests because it failed to recognize the importance of recurrent fires for their functioning and persistence, as Pyne (1982: 184–198), among others, has shown. But in most places, fires were a function not so much of the trees themselves, but of the grasses that grew beneath and between them, providing the fine fuels in which recurrent fires could start and spread. European forestry's ignorance of—and prejudice against—fire, then, reflected its ignorance of grasses, which in the European context were deemed important only in "improved" pastures that were both spatially and intellectually segregated from forests. This division of scientific labor transferred directly to the US as well. Pinchot had to reach outside his agency to initiate scientific studies of the range. And after the Forest Service absorbed range research a few years later, the interests and priorities of forestry would dominate the fledgling field of range science for decades to come.

2 Conception of the experiment

Frederick Vernon Coville (1867–1937) was the son of a bank director in upstate New York. After graduating from Cornell, he was hired as Assistant Botanist in the USDA in 1888, and five years later he succeeded George Vasey as Chief Botanist and honorary Curator of the National Herbarium. He is most famous for his work as a botanist, especially in connection with the Death Valley Expedition of 1891, and for his path-breaking research on the blueberry, which helped make it a commercial crop in the northeastern US. Although less well known, his role in charting the course of rangeland research and administration must be considered among his most enduring accomplishments. For Roosevelt's Public Lands Commission, he wrote the blueprint for the grazing lease system subsequently adopted by the Forest Service (Potter and Coville, 1905), and his fieldwork and reports in the decade after 1897 set the terms of engagement for public range grazing research. As Pinchot succinctly put it years later, "Until the Forest Service developed a body of experts of its own, Frederick V. Coville was the first and the earliest authority on the effect of grazing on the forest" (quoted in Maxon, 1937: 280).

Struggling to define and assert management authority over the forest reserves, the General Land Office had banned all livestock grazing in 1894, believing it necessary to protect forest regeneration and reduce fires. The move provoked resistance from sheep and cattle owners throughout the West, and at the end of June 1897, new policies were announced rescinding the ban for cattle nationwide but retaining it for sheep, except in the reserves of Oregon and Washington, where "the continuous moisture and abundant rainfall . . . make rapid renewal of the herbage and undergrowth possible" (quoted in Coville, 1898: 11). A week before announcing the partial rescission, the Secretary of Agriculture instructed Coville "to make an investigation of the alleged damage to forests by grazing of live stock [sic], more especially the effects of sheep herding in the Cascade Forest Reserve of Oregon," which had been created in September 1893. His subsequent report (Coville, 1898) clearly articulated the empirical and analytical framework from which the Coyote-Proof Pasture Experiment would later be designed.

Coville's field methods were both ecological and ethnographic,[9] and he came to see fencing, herding, and predators as tightly inter-related elements of the problem of the western range. To begin with, he emphasized the distinction between "farm sheep" and "range sheep," pointing out that whereas the former were fenced, the latter were herded,

> on the great areas of unfenced public or Government land, popularly known as the open range, the outside range, or simply the range. Because this land is not fenced, and because unprotected sheep would be liable to destruction by wild animals, especially coyotes or prairie wolves, these range sheep are accompanied and cared for by a man who is called a sheep herder, or simply a herder. As a matter of economy, each herder is intrusted [sic] with as many sheep as he can properly manage, commonly two or three thousand (Coville, 1898: 9).

Coville firmly rebutted two widespread claims about sheepherders: first, that they were "aliens" or non-citizens who represented "a comparatively low class of humanity" (Coville, 1898: 12); second, that they were responsible for starting forest fires. These were politically volatile (and brave) arguments to make, and they stood in sharp contrast to the prevailing views of many prominent figures, such as John Muir, who famously described sheep as "hooved locusts" and whose vision of wilderness erased and excluded both non-whites and laborers of all kinds (DeLuca and Demo, 2001). Coville sidestepped the polemics, apparently considering both of his claims to be settled by the facts on the ground. Instead, he focused his analysis elsewhere, detailing the herders' management techniques, their knowledge of the value of different plants for sheep growth, and the variation in their skills. He noted that "The acreage per sheep required for grazing throughout the summer is exceedingly variable, depending on the kind and character of the vegetation" (Coville, 1898: 18). Above all, he made the case that sheep grazing could be managed such that it would be—in today's terminology—sustainable, and to do this he likened the range to a pasture:

> The effect of a moderate amount of grazing on the lands of the reserve is the same as the effect of the judicious removal of a grass crop from a fenced pasture by grazing or from a meadow by cutting; namely, that a forage crop is secured without material detriment to the land and the herbaceous vegetation it bears . . . By "a moderate amount of grazing" is meant grazing only to such an extent that the forage crop does not decrease from year to year (Coville 1898: 26).

Overgrazing in the Cascades had occurred, according to Coville, but it was neither ubiquitous nor longstanding, and it had not yet altered the composition of vegetation in the reserve. He attributed the damage he observed not to the herbivory of the sheep but to their physical movements. "The principal bad effects of overgrazing are to be attributed rather to trampling than to actual close cropping" (Coville, 1898: 27). This could be prevented, he believed, by securing sheep owners' access to the range resource. Open access for all made each herder rush to use the range ahead of the others, "to get all the grass possible without reference to the next year's crop, for he [the herder] is never certain that he will be able to occupy the same range again. Where the competition is close the difficulty of insufficient forage is increased by the haste of the herder in forcing his sheep too rapidly over a grazing plot, the result being that they trample more feed than they eat. So year after year each band skins the range" (Coville, 1898: 50). A system of permits to graze specified areas would relieve this competition, and also enable the government to impose other terms, such as stocking rates and rules regarding fires.

Coville conducted similar fieldwork in Arizona in 1900 at the invitation of Pinchot. The conflict there also concerned sheep grazing, but in relation less to timber and fires than to watershed conditions above the Salt River, whose waters were being developed for irrigation in the Phoenix basin below. The trip was proposed and hosted by Alfred F Potter, a prominent local sheep owner and secretary of the Arizona Wool Growers' Association. After a three-week wagon tour of the Mogollon Rim country, Coville and Pinchot concluded, as in Oregon before, that sheep grazing should be permitted but carefully regulated. Shortly thereafter, Pinchot recruited Potter to come to Washington as Assistant Forester in charge of the Branch of Grazing. Potter and Coville would later author key parts of the Public Land Commission's 1905 report, making the case for exclusive leases to graze fenced allotments of the western range. The trip also cemented a long-lasting friendship between Coville and Pinchot.

3 Implementation of the experiment

In late March of 1907, Pinchot and Potter met with CV Piper, Chief Agrostologist in the BPI, to discuss "the range investigations which they would like to have undertaken by this Bureau." In a memo the following day, Piper reported to Bureau Chief BT Galloway that the Forest Service had reduced stocking on northwestern sheep ranges by about 25 percent, "by agreement with the stockmen. It is however the desire of the Forest Service to increase the carrying capacity of these summer ranges and consequently the allotment of stock to each district as rapidly as possible," and "to permit as many stock as possible to run on these summer ranges." Experiments were needed to determine whether degraded ranges could be reseeded, and to determine,

> what system of range management both with cattle and with sheep will best permit the more valuable native grasses to re-seed themselves and thus increase the carrying capacity and maintain it at a maximum . . . The investigations will not only be necessary to the best administration of these range lands but will result in enormous benefit to the live stock interests of the West.

Piper recommended that JS Cotton, who had studied range conditions in central Washington (Cotton, 1904) be put in charge of the experiments. It appears Pinchot overrode this suggestion in favor of Coville. An inter-bureau agreement was reached that the BPI would cover Coville's salary and expenses, while the Forest Service paid the rest of the costs.

In mid-May, Coville headed west to set up the experiments. From his hotel in Lincoln, Nebraska, he wrote to Pinchot:

> After a conference with Professor [Charles] Bessey and Professor [Frederic] Clements, and with the prospective appointee himself, I have secured one of the men we want for the forest grazing experiments. He is Mr. Arthur W. Sampson, a resident of the state of Nebraska, and a graduate student of the University. He is an expert in plant ecology and should be appointed as such.

Sampson's training under Bessey and Clements was critical for Coville because it meant that the other men he hired would not need expertise in botany or ecology; its importance for the future of range science was even greater, because it helped install Clementsian ecological theory as the foundation for the discipline. Five days later, in Logan, Utah, Coville hired Jardine, describing him thus to Pinchot:

> Mr. Jardine is twenty-five years old, a graduate of Utah agricultural college, and now an instructor in that institution. He was brought up on a ranch in southern Idaho and is familiar with the handling of cattle, horses, and sheep. He is well qualified both by his personal characteristics and his training to take part in the forest grazing investigations.

En route from Lincoln to Logan, Coville stopped in Laramie, Wyoming, to interview a prominent sheep owner by the name of Francis S King. An immigrant from England, King and his brothers owned or leased some 120,000 acres of private land in Wyoming and were famous for their prize-winning purebred Merino, Rambouillet, and Corriedale rams and ewes (Bartlett, 1918: 59). Coville's notes from the meeting suggest that King's ideas and opinions played a significant role in refining the details of the imminent experiments in Oregon. King saw two advantages to protecting sheep within a predator-proof enclosure: reduced labor costs and improved animal performance:

Lambing within a wolf and cat proof fence would be highly advantageous, because three men could lamb 2500 ewes, one to keep the drop herd bunched and moving, one to move each lamb and ewe to shelter, one to look after the lambs for a day or two. Mr. King now has to use 5 men with each half band of 1500 lambing sheep. These men are kept with the half band about 10 days. Such temporary help is often not trustworthy. On a wolf and cat proof range two men could care for 8000 to 10000 sheep.

King reported results from his own kind of experiment to support the claim that sheep would gain more weight and produce more wool if fences replaced herders, because the animals' behavior would change.

When lambs bunch together as they do when a band beds down [on the open range], they run off a large amount of fat in racing and playing. A bunch of 37 thoroughbred lambs run in a band averaged about ten pounds lighter than the same number of lambs the following year from the same dams and sires run in a pasture on grass not quite so good. Difference of $3.50 in price of lambs. The ewes sheared 2 to 3 pounds more.

The core problem, according to King, was the herding system itself, with all that it entailed: unreliable laborers moving sheep in bands or bunches across open range in the presence of predators. Coville noted "from 5 to 15 percent loss from herding and wild animals," and he listed numerous reasons to be rid of herding:

- Five per cent of lambs lost on account of herding system;
- One per cent loss in grown sheep due to herding system (Three percent is customary loss of old sheep from all causes);
- Saving in herding;
- Carrying capacity of range, probably double;
- Condition and value of stock and wool;
- Sheep fatter, healthier, wool worth more.

These were the expectations that Coville carried into the experiment when he arrived in Oregon in late May.[10] Even before real data were available, he expressed his views in the introduction to Jardine's first report, published the following year. Both herders and herding represented obstacles to the efficient use of range resources on the national forests:

A large loss of vegetation by trampling is inherent in the herding system itself. Even with the best herders it is impossible to handle large bands of sheep with the same grazing efficiency as is secured in the fenced pastures of the eastern United States, and when one considers the large percentage of herders who are not skilled or who have a greater regard for their own comfort than for the interests of the owner of the sheep or for the permanent welfare of the range, the aggregate waste can be regarded in no other light than as a matter of serious public concern. That one-third of the vegetation on the sheep ranges in the National Forests is destroyed by trampling is regarded as a conservative estimate (Jardine and Coville, 1908: 5–6).

Where this estimate came from is not clear, but it gained traction as a means of asserting the importance of finding an alternative to herding. Jardine used it, for example, to convert the impacts of trampling to dollar figures for the national forests as a whole: "It is estimated that the gross income of sheep owners last year from the grass in the National Forests was $7,225,000, and that the grass trampled and wasted represents a possible additional gross income of about $3,500,000" (Jardine and Coville, 1908: 6). Trampling represented a double loss: not only of forage not eaten, but also of weight and wool not produced due to wasteful expenditure of the sheep's energy.

On June 3, Coville reported to Pinchot that he had selected a site with good forage, ready access by wagon, and "an abundance of coyotes, wild cats, and bear, with an occasional cougar and lynx." "The stockmen" in the area, he wrote, "are greatly interested in the experiment, the consensus of opinion being that under a pasture system the carrying capacity of the range will be doubled." He had found a "thoroughly efficient hunter" to hire for the project, and he recommended some modifications to the fence design based on his conversations in Wyoming (presumably with King). He had also

Figure 1. The coyote-proof pasture fence, Wallowa National Forest, 1907, shortly after construction. Trees were cleared for 10 feet on either side of the fence to prevent wild cats from leaping over from overhanging branches. One strand of barbed wire was stretched along the ground surface to discourage predators from digging underneath. Photo courtesy of the National Archives, College Park, MD.

met with the press to promote the experiment. One reporter wrote:

> It is believed that the same amount of grass will support many more sheep when they are pastured than when they are herded. Should this theory be proved, the result will revolutionize the entire policy of the department in regard to the reserves and will have a great bearing upon the stock industry.[11]

By mid-June, Jardine and Sampson had reported for duty, the fence was under construction, and Coville soon returned to Washington. The fence—an imposing and elaborate combination of barbed wire, wire mesh, and stout posts (Figure 1)—was completed too late for a full season's research, but a band of sheep was placed in the new pasture for one month and observations were made both of their behavior and of the effectiveness of the fence at repelling predators. As for the latter, "the fence proved successful as a protection against coyotes, not successful as a protection against grizzly bears, doubtfully successful against black and brown bears, still problematic against cats, and not successful against badgers" (Jardine and Coville, 1908: 23). The hunter and his hounds patrolled the perimeter each day, recording signs of predators and, when possible, pursuing them (Figure 2). But just as Merriam had feared, one coyote was trapped inside the completed fence, and two sheep were lost to predators—one to a bear and another to the coyote (Jardine and Coville, 1908: 21). These predators interfered with efforts to observe "the action of sheep when they are allowed perfect freedom in an inclosure [sic] and protected from annoyance by animals" (Jardine and Coville, 1908: 25), but Jardine nonetheless judged that "the test was very satisfactory. They [the sheep] retained, more or less, the natural instinct to mass, but from the first day the tendency to open, scattered grazing, with little or no trailing, increased" (Jardine and Coville, 1908: 29). While conceding that solid data had yet to be collected, Jardine concluded: "That the experimental system will materially increase the carrying capacity of the range is not to be doubted" (Jardine and Coville, 1908: 32).

4 Conducting the experiment

The following summer, after repairs had been made to the fence, a band of 2209 sheep was turned into the coyote-proof pasture without a herder. The hunter resumed his daily patrols, and the behavior of the sheep was monitored all day, every day from June 21 to September 24. Only 15 sheep died during the 96 days, none due to predation. The objective was to induce "open grazing," as Jardine termed it.

> Whether sheep are in large or small bunches it is essential for the protection of the range that they be

Figure 2. JK Carper, the hunter hired to patrol the coyote-proof pasture, and his hound, 1908. Photo courtesy of the National Archives, College Park, MD.

> well scattered and graze quietly. Close-bunched grazing, massing, running, and trailing one after another should be prevented if possible, not only for the good of the range but for the good of the sheep. In this respect there was marked change during the season (Jardine, 1909: 23).

Here, the predators were not the only culprits: herders themselves, and especially herders' dogs, were like predators in that they could provoke fright in sheep and cause them to bunch, mass, and run. But the fence removed herders and dogs as well as predators, and over the course of the summer, "the sheep gradually became accustomed to free, unmolested grazing, and forgot the habits learned when herded" (Jardine, 1909: 23). They formed smaller bunches, both while grazing and also to sleep at night, and they moved more lightly over the landscape. "The result was that little or no damage was done to the forage crop in this way. The entire crop was eaten and not wasted" (Jardine, 1909: 23).

By weighing 20 lambs "of average size" at the beginning and end of the experiment, and collecting similar data from bands herded on the range nearby, Jardine was able to compare animal performance under the two systems. In 88 days inside the fence, the pastured sheep gained an average of 20 pounds, whereas those from a band on the outside gained only 15 pounds, on average, in 96 days. Overall losses among four outside herds ranged from 1.4 to 3 percent, compared with just 0.5 percent for the fenced herd. Finally, the fenced sheep required only 0.0156 acres per sheep per day. Three open range herds, roughly estimated, required 64–123 percent more acreage, which Jardine attributed to the effects of trampling (and, in one case, "poor herders, who were of French descent, unable to speak English" (Jardine, 1909: 32)). "It is safe to conclude that range grazed under the pasturage system will carry 50 per cent more sheep than when grazed under the herding system, where the band is driven to and from camp each day" (Jardine, 1909: 32).

In the closing pages of his report for the 1908 season, Jardine took up the economic question: "Will the pasturage system pay?" Here he faced a difficulty, because the coyote-proof pasture had been very expensive to construct: $6764.31, to be precise, including more than $2000 in materials, $1000 in transportation costs, and $1000 to clear heavy timber from portions of the fence line (Jardine and Coville, 1908: 18–19). This amounted to nearly $850 per mile (equivalent to over $22,000 in 2014 US dollars). Jardine chose not to use these figures, however, arguing that the location was exceptionally remote and heavily timbered. Using more general estimates, he calculated that "the cost on most grazing lands will approach very closely $400 a mile" (Jardine, 1909: 39). He then tabulated the financial benefits in increased carrying capacity, heavier sheep, reduced losses to predation, and lower labor costs. Not counting increases in the lamb crop and in the amount and quality of wool (which he considered to be certain but not yet measureable), Jardine arrived at an annual return of $746.50, based on a herd of 2200 sheep in a 2560-acre pasture for three months. Thus, an initial investment of $3200 (for eight miles of fence), at 8 percent interest and including maintenance, would pay for itself and begin yielding dividends after six years. He did not include the costs of the hunter in his analysis.

The experiment was repeated in 1909 with 2040 sheep enclosed in the pasture for 99 days, during which time only four perished. The results were nearly identical to those from 1908, although Jardine's report was more detailed and more emphatic in its declarations of the virtues of "the pasturage system." The hunter killed one grizzly, two badgers, seven brown bears, and seven coyotes (the grizzly was killed even though it made "no attempt to go through [the] fence"), and just one brown bear and three badgers managed to breach the fence (Jardine, 1910: 8). The sheep again displayed a gradual tendency "to depart from their old habits and accommodate themselves to the freedom of the pasture," so much so that by the end of the season "it was almost impossible to keep them close bunched without a dog" (Jardine, 1910: 18, 19). Losses to poisonous plants, as well as predators, were higher among sheep herded outside the enclosure, and the pastured sheep were again heavier at the end of the season than the herded sheep (although this may have been due to differences in breeding) (Jardine, 1910: 25). Acreage required per sheep per day was 52–90 percent higher outside the fence, although Jardine attributed some of this to poor quality herders (including the one of French descent, again, though by this time he had learned a little—"very little"—English) (Jardine, 1910: 27–28).

The issue of herder skill presented a puzzle, which Jardine acknowledged but failed to address directly. "A first-class herder will work all the time" and seldom use a dog, resulting in "quiet, scattered grazing that may approach the pasturage system in efficiency" (Jardine, 1910: 31), whereas "a lazy man . . . will wear out his dogs, worry the sheep, and destroy the forage" (Jardine, 1910: 32). With respect to weight gain, "there is as much difference in the results obtained by a first-class herder and those obtained by a poor herder as there is between the results under the pasturage system and those secured by the good herder" (Jardine, 1910:

26). And while "range grazed under the pasturage system will carry from 25 to 50 per cent more sheep than when grazed under the herding system," it was also possible "that an excellent herder can, to a considerable extent, allow his sheep freedom and keep them quiet, thereby increasing the carrying capacity of his range. No doubt there are herders who do this" (Jardine, 1910: 28). All told, "the carrying capacity of the same range utilized by different herders may vary at least 25 per cent" (Jardine, 1910: 31).

These were potentially troublesome admissions to make, for both scientific and economic reasons. Herder skill was clearly an important variable in sheep performance, but it was one that Jardine could neither measure nor control. Removing herders might thus be seen as necessary to a properly "scientific" assessment of range grazing. And it could clearly affect any calculation of the economic rationality of building fences and controlling predators. What if better training for herders were a more economical solution? Instead of confronting these issues, Jardine reverted to general claims about labor needs under the pasturage system, superseding by half the estimate that King had given to Coville two years earlier: "It is probable that one energetic man . . . can properly care for four inclosures [sic] similar to the experimental coyote-proof pasture," meaning "one man would care for from 8,000 to 10,000 head of sheep" (Jardine, 1910: 22).

Notwithstanding these problems, Jardine reached the same conclusions in 1909 as he had the year before.

> When left unmolested by herders and dogs in an area protected against destructive animals, a band of ewes and lambs will accommodate themselves to the freedom of such a system and will separate into small bunches, coming together occasionally but again separating. With few exceptions they will graze openly and quietly (Jardine, 1910: 28–29).

Losses will be slight, weight gain and wool clip will improve, carrying capacity will increase by 25–50 percent, and labor costs "will not exceed 25 per cent of the cost under the herding system" (Jardine, 1910: 29). Although he did not present numbers for 1909, he again concluded that "the increase in carrying capacity and decrease in expense of handling in pasture during the lambing season will justify the cost of construction necessary to inclose [sic] the entire allotment" (Jardine, 1910: 40).[12]

The Wallowa experiment was hailed as a remarkable success, and the Forest Service quickly embraced it as guidance for the administration and management of rangelands generally. It appeared to solve numerous problems and satisfy everyone, provided one ignored or excluded the herders. In his "Annual Report to the Forester for the Fiscal Year 1909–1910" for the Branch of Grazing, Potter described the results as "very gratifying" and summarized them as follows:

> The primary objects of the experiment have been accomplished, i.e. it has been demonstrated that the grazing capacity of the Forest lands can be largely increased by improved methods of handling stock, and that the increased cost of such methods, if any, is offset by increases in the number and weight of lambs raised, heavier wool crops, and reduced losses from predatory animals.

Notably, Potter omitted any reference to labor costs in his summation. He suggested that the results be applied "to spring and fall or yearlong ranges" in other national forests. Elsewhere in his report, Potter tabulated the accomplishments of Forest Service personnel assigned to predator control: 269 bears, 129 wolves, 148 wolf pups, 1155 wildcats, and more than 7000 coyotes killed in the 11 western states, "an increase of 109 per cent over the number of animals destroyed last year" and representing "a total saving to stockmen of considerably more than one million dollars per year".

III Conclusions

A CPG of the Coyote-Proof Pasture Experiment reveals two important insights. First, the institutional context in which science is practiced may be at least as important as the experiments and findings that the scientists produce. Livingstone (2003) has shown the importance of place to the conduct of science, and the geographical particulars—both social and ecological—of the Wallowa site attracted Coville to locate the study there. But the larger context was a national one, and, in this case, not only did it shape the questions that were asked and define the terms of success, but the success caused the institutional context itself to change, setting in motion a path dependency for subsequent research and management of rangelands elsewhere. The particularities of the Wallowa site were abstracted away so that the results could be taken as relevant to rangelands throughout the western US.

Second, although the findings of the experiments were presented as scientifically robust, *ecological* facts—in which predators, livestock, fences, and vegetation interacted in measurable ways—the methods were weak and the ultimate metric for evaluating success was actually an economic one. Costs and returns, and thus profit on investment, determined whether fencing and predator control were worth implementing. In this calculus, the decisive factor was neither fences nor livestock performance but rather the labor of herders. The high cost of fencing could be justified economically only if the fences greatly reduced the need for herders—and in the absence of herders to protect livestock, predators would have to be rendered effectively insignificant. What is more, even the economic analysis was flawed, with key costs either minimized or excluded in order to reach the desired conclusion.

By today's scientific standards, the Coyote-Proof Pasture Experiment was far from impressive. The methods varied in several ways from one year to the next, and they were reliant on qualitative assessments or herder accounts for some important data. The findings were confounded by sheep breeds, herder practices, vegetation types, and other variables, and no direct attempt was made to assess the impacts of the pasturage system on vegetation. Moreover, there were no real controls by which to judge the relative effects of the enclosed pasture, the absence of predators, and the absence of herders or dogs as factors influencing the dependent variables (weight gain and wool clip). Estimating the carrying capacity outside the fence was imprecise, since those herds were not confined within fixed boundaries. Finally, the economic calculations excluded the costs of the hunter, and did not account for the actual costs of the fence. Virtually every finding looks suspiciously similar to the expectations that Coville carried into the experiment in 1907. Moreover, Jardine's reports were not subject to peer review, but only to the scrutiny of his superiors in the USDA, who themselves appear to have pre-judged the results. There is almost no chance that the experiment would be recognized as publishable, or even scientific, if it were conducted today.

The experiment succeeded not on the basis of its scientific rigor, but instead because it lent authority to ideas that were already viewed favorably within the institutional context that gave rise to it. Coville and Jardine produced a set of knowledge claims that appeared to conform to scientific norms of experimentation: the deliberate manipulation of objects, organisms, and people, and the careful recording and interpretation of actions and reactions among them. Most of these primary data were of a broadly ecological character, and thus appeared as apolitical and "objective." The results were translated into economic terms to assess the practicability of implementing a similar management regime on western rangelands as a whole, and if the economic analysis was at once flawed and decisive, this contradiction would be resolved by government largesse: the cost of both fencing and predator control would be subsidized by an array of federal agencies over the decades to come. Predator control occurred throughout the national forests and beyond, much of it organized and funded by the Bureau of Biological Survey under federal legislation passed in 1914; fencing was underwritten by the Forest Service,[13] the General Land Office's Grazing Service, and the Civilian Conservation Corps, whose crews built thousands of miles of fences between 1933 and 1942. Much simpler and cheaper, four-strand barbed wire fences were used—rather than the elaborate Wallowa design—as hunting, trapping, and poisoning reduced predator populations region-wide.

If both fencing and predator control were already planned or ongoing, and might well have proceeded without "scientific" support, then the greater significance of the Coyote-Proof Pasture Experiment lies in the ways it altered the institutional context itself, and thereby the trajectory of rangeland administration and research. Jardine and Sampson were quickly elevated from "special agents" to permanent positions in the Forest Service, becoming "the two pioneers in national forest-range research" (Chapline et al., 1944: 131). Jardine was promoted to Inspector of Grazing in charge of the new Office of Grazing Studies in 1910, overseeing range research and directing the monumental task of "range reconnaissance" throughout the national forests over the following decade (Chapline et al., 1944: 131). He later served as Chief of the Office of Experiment Stations and Director of Research for the USDA. Sampson was appointed to head the new Utah Experiment Station (later renamed the Great Basin Experiment Station) on the Manti National Forest, where he worked until 1922, when he accepted a newly created academic post in range science at the University of California-Berkeley. Both authored reports in 1919 that rank among the most influential in the history of US rangelands: Jardine's *Range Management on the National Forests* (Jardine and Anderson, 1919) was the first comprehensive statement of the policies and principles guiding forest rangeland management. It was still in use at his retirement in 1945—having been "three times reprinted without change"—when he was described as having "brought out the principles on which are founded the standards of good grazing practice over the whole western range country" (Rand, 1945: 2). Sampson's "Plant Succession in Relation to Range Management" (Sampson, 1919) established range science on the basis of Clementsian ecological theory. For governmental and scientific purposes, respectively, Jardine and Sampson became the principal architects of the dominant paradigm affecting US rangelands in the 20th century. It relied on fencing and predator control not only to remake the physical landscape in favor of livestock production, but also to modify the social landscape, reducing livestock owners' dependence on herders to tend and protect their animals. In this realm and many others, the policies of the Forest Service benefited some people at the expense of others, and the agency relied heavily on "science," howsoever flawed, to buttress its legitimacy (Rowley, 1985).

With the creation of the Office of Grazing Studies within the Forest Service, moreover, a critical bureaucratic shift took place, apparently without comment or resistance. The scientific challenge of studying grasses, grazing, and rangelands passed from the BPI into the hands of the Forest Service, first under the umbrella of the Branch of Grazing and then, after 1926, the Branch of Research. There is no indication that Coville objected to this transfer of research authority, and perhaps he could not have foreseen its longer-term consequences. Foremost among these consequences was the permanent subordination of range research to the Forest Service's core mandate, timber production, and to its corollary imperative of fire suppression. What this meant, in practice, was that range researchers would be discouraged, if not prohibited outright, from investigating the possible benefits of fire to grasslands, savannas, and forests throughout the West for most of the 20th century. It is impossible to know what might have happened had range research remained in the portfolio of the BPI, but there is reason to believe that fire might well have been viewed in a more favorable light, at least in certain parts of the country such as the Southwest (Griffiths, 1907, 1910).

The effects of the Coyote-Proof Pasture Experiment extend down to the present and across literally hundreds of millions of acres of rangelands in the US and elsewhere. It contributed directly to policies of fencing the land into pastures and eradicating predators of all kinds in the belief that these measures would benefit both livestock production and rangeland conditions. Fencing has since become ubiquitous and almost unquestioned as a basic tool of ranching and rangeland management, subsidized by US government agencies and aggressively promoted in pastoral development projects overseas; Netz (2004), who acknowledges that the US West was where barbed wire fencing found its first widespread use, goes so far as to view it as fundamental to the "ecology of modernity." Many predators continue to be persecuted by the BBS's descendent agency, Wildlife Services; even those that are not persist only at much reduced numbers. Perhaps most importantly, the Wallowa experiment contributed indirectly to institutionalizing range research in an agency whose primary mission lay elsewhere, inhibiting scientific recognition of the ecological importance of recurrent fires. The ecological effects of fencing probably cannot be disentangled from the other factors it enables or accompanies, such as water development, reduced herd mobility, and land tenure rationalization; suffice to say that fragmentation is considered a major threat to rangelands worldwide (Galvin et al., 2008). The magnitude of the influence of predators on ecosystem processes is controversial (Marris, 2014), but there is wide agreement that the consequences of long-term fire suppression are profound (Pyne et al., 1996).

CPG reveals the concatenation of particular events that influenced the Coyote-Proof Pasture Experiment, while simultaneously illuminating the institutional and political conditions that enabled it to have such widespread effects. We can then ask new questions about present-day issues and debates concerning rangeland conservation and management. In recent decades, scientists and environmentalists have challenged many predator control programs, and some extirpated predators, such as wolves, have been protected and/or reintroduced in portions of their former species ranges. But fencing is rarely challenged. In view of the history recounted here, one has to wonder if restoring predators can only be compatible with continued range livestock production if herding, too, is restored—in which case fences may no longer be necessary.

Acknowledgements

I am grateful to Kris Havstad, Joel Brown, Brandon Bestelmeyer, George Ruyle, and Curt Meine for their encouragement and ideas over the years; to Rebecca Lave for convening this special issue and inviting me to participate; to the many helpful archivists at the National Archives in College Park, Maryland; and to George Malanson and three anonymous reviewers for valuable suggestions on earlier versions.

Funding

The research for this article—and a larger book project of which it is a part—was supported by the USDA-ARS-Jornada Experimental Range and by the University of California-Berkeley Committee on Research.

Notes

1. No scholarly monograph on the history of range science exists. One doctoral dissertation on the topic has been written (Heyboer, 1992), and another, more recent dissertation devotes a chapter to it (Pearce, 2014).

Critiques of conventional range science have come primarily from scholars working in Africa and Australia (e.g. Behnke et al., 1993), with very limited attention to the history of the discipline in the US. Many histories of the Forest Service have been written, some specifically about rangelands (e.g. Rowley, 1985) or Forest Service research (e.g. Steen, 1998), but none has devoted more than 16 pages to range science. One chapter of Sayre (2002) recounts the history of range science in Arizona. The rest of the literature consists of a handful of journal articles by range scientists, most notably Chapline et al. (1944).

2. The Imnaha National Forest was established on March 1, 1907, by the combination of the Wallowa and Chenismus National Forests, which had been established by President Roosevelt in 1905. On July 1, 1908, the name was changed to Wallowa National Forest, and in 1954 it was combined with the Whitman National Forest to create the Wallowa-Whitman National Forest. (Richard C Davis, 2005, "The National Forests of the United States," The Forest History Society. Available at: www.foresthistory.org/ASPNET/places/National%20Forests%20of%20the%20U.S.pdf (accessed 12 July 2013).
3. All quotations without references are from the records of the US Forest Service (Record Group 95) and the Bureau of Plant Industry (Record Group 54) in the National Archives, College Park, Maryland. Copies of the quoted documents are available from the author.
4. Merriam's memo was accompanied by specifications for the proposed fence prepared by Biological Survey employee, Vernon Bailey, who was also Merriam's brother-in-law and long-time specimen collector (Jardine and Coville, 1908). Bailey's designs for predator-proof fencing are detailed in Bailey (1907).
5. Smith (1898) describes what is probably the first such experiment, at least the first by government researchers.
6. According to USDA data, cattle losses from animal predators in 2010 totaled 219,900 head, more than half attributed to coyotes. Although valued at nearly $100 million, this represented less than one-quarter of one percent of the national herd. Eighty-two percent of losses were calves. Predation by dogs exceeded that by wolves by nearly 270 percent (21,800 to 8,100). Predation of sheep totaled 247,200 head; of goats, 180,000 head. In the 11 western states, cattle and calf losses totaled 55,000 head and sheep and lamb losses totaled 119,700.
7. For example, replacing the top and bottom strands of barbed wire fences with smooth wire is a recognized "wildlife-friendly" practice supported by government conservation programs, but predators are not really the intended beneficiaries. Meanwhile, the protection or reintroduction of predators has gained traction—and provoked controversy—in recent decades, but fence removal has not been proposed as a way of advancing the cause.
8. This last shift was partially facilitated by another set of experiments, also designed by Coville, which were conducted concurrently with the Coyote-Proof Pasture Experiment by the young Arthur Sampson. There is not space here to explore Sampson's experiments in detail; I will treat them in future publications.
9. "We traversed, besides the well known parts of the Cascades, some of the most remote and inaccessible portions, where, traveling largely without trails, we interviewed sheep owners, packers, and herders, cattle owners, and all classes of people; both those who favored and those who were opposed to the permitting of sheep grazing within the reserve. We followed the bands of sheep as they were grazing, watched their movements, their choice of forage, and the methods of handling them; observed the effects of both recent grazing and of the grazing of former years; and investigated the devastation caused by fires. Areas of the forest were examined in every stage, from total immunity from fires to total destruction by them" (Coville, 1898: 7–8).
10. Coville may also have been influenced by reported results of fencing out predators to protect sheep in Australia and South Africa. In a 1905 Bulletin of the Biological Survey, David Lantz (1905: 23) gave a nearly identical list of advantages, beginning with "decreased cost of herding," from a paper read by the president of a farmer's association in Cape Colony, South Africa.
11. A clipping of the article, entitled "New Policy in Reserves: Government experiments in grazing them" and bylined "Wallowa, Or., June 2" is in Coville's papers in the National Archives, with a handwritten note attributing it to the *Oregonian* of June 3, 1907. This appears to be in error, however, as no number of that newspaper was produced at that date.
12. Although the Wallowa experiment did not involve lambing—that is, the handling of ewes and lambs during the birthing (or yeaning) period—Jardine took a

keen interest in the question of whether the pasturage system would also work for this purpose. At first he relied on reports from private sheep owners who had implemented variations along similar lines on their own (Jardine, 1909, 1910, 1911); later he oversaw an experiment in the Cochetopa National Forest in Colorado (Jardine, 1911). I have not treated these in detail here because the conclusions he reached were so similar to those reached in the Wallowa experiment. On the critical issue of economic returns, for example, the conclusion was identical: at 8 percent interest, a coyote-proof lambing pasture would pay for itself and produce a dividend after six years (Jardine, 1911: 32).

13. In the 13 national forests in the southwest region of the Forest Service, for example, 4153 miles of fence were constructed between 1925 and 1933, at a total cost of $851,000 (more than $15 million in 2014 dollars); the agency paid 49 percent of this cost, while ranchers paid the rest.

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