THE COMPARATIVE INSTITUTIONS APPROACH TO WILDLIFE GOVERNANCE

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Abstract. This paper develops a comparative institutions approach to wildlife governance that relies on an examination of the property rights to the habitat and the stocks of wild populations. The approach is based on the transaction cost – property rights approach and lies primarily in the traditions of Coase (1937, 1960), as well as Barzel (1997), Ostrom (1990) and Williamson (1985).   The approach recognizes the often-extreme costs of delineation and enforcement of property rights to wild populations and their habitat and thus all systems are notably imperfect compared to the typical neoclassical economics approach. These costs arise because wildlife habitat and wildlife populations are part of the land which has many attributes and uses, most notably for residential and agricultural uses.   In turn, the optimal ownership sizes (and shapes) vary across land uses (e.g., farming, urban, ranching, wildlife, parks). The organizations that govern wildlife tend to be ridden with transaction costs and imperfect property rights and the most efficient system is one that maximizes the total value of the package less the enforcement and administrative costs.   An economic framework is developed for considering different governance regimes for both the wild stocks and the habitat they require.   A series of cases -- focused especially on bison and caribou -- that show the range of governance regimes that have been used and how those governance regimes depend on history and on law.

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If it was the common law that sheep and lambs belonged to nobody, it would be impossible to preserve them from utter destruction.   Each man, when he saw a sheep or lamb, would take and sequester it for his own use, lest his neighbor should get the start on him. There is no common or statute law [in the United States] protecting fish and game, therefore our fish and game are rapidly disappearing. What we need is a law, not simply protecting game and fish... but making game and fish the property of the owners of the land on which they are found, and the streams through whose territory they run.[1]

1.   INTRODUCTION

The conservation and management of wildlife populations have been governed by a wide array of organizations and legal regimes over time and across space. Consider, for example, governance of the American bison (locally called the buffalo).[2]   Today, many bison are privately owned like domestic cattle, but some are also under the administration of national park managers and state wildlife agencies where the ownership is less clear. Prior to extensive European contact, Native Americans governed bison as common property with enforcement of hunting territories against other tribes and internal tribal rules about hunting times and methods. During the 19th century as the indigenous peoples were conquered, the bison stocks were subjected to open access depletion and nearly exterminated before they ultimately become governed largely as domestic animals under state agricultural laws.

Caribou are governed as wild animals in North America, subject only to full ownership upon harvest.   In Europe, however, where they are called reindeer, they are partly domesticated and governed as private (sometimes communal) property. Both are the same species, *rangifer tarandus*. Many other examples of the same species differentially governed can be given and several are discussed below.

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[1] *Forest and Stream* (volume 5, January 13, 1875, page 361) and cited in Tober (1976, p.122.
[2] Lueck (2002) examines the economic history of the bison.

This paper develops a comparative institutions approach to wildlife governance that relies on an examination of the property rights to the habitat and the stocks of wild populations. The approach is based on the transaction cost – property rights approach and lies primarily in the traditions of Coase (1937, 1960), as well as Barzel (1997), Ostrom (1990) and Williamson (1985). The approach recognizes the often extreme costs of delineation and enforcement of property rights to wild populations and their habitat and thus all systems are notably imperfect compared to the typical neoclassical economics approach. These costs arise because wildlife habitat and wildlife populations are part of the land which has many attributes and uses, most notably for residential and agricultural uses. In turn, the optimal ownership sizes (and shapes) vary across land uses (e.g., farming, urban, ranching, wildlife, parks). From this point, it is easy to see that land with more than one characteristic (e.g., farm land and wildlife habitat or a watershed) will create property regimes that may not match the geographic boundaries of habitats and populations. Even in the case in which wildlife and its habitat are the only valued characteristics of the land the large scale may lead to large organizations to effectively control the resources. These organizations will be ridden with transaction costs and imperfect property rights and the most efficient system is one that maximizes the total value of the package less the enforcement and administrative costs.

The economic framework in this essay uses the property rights typology of Lueck and Miceli (2007): open access, common property, private property, and state property. Open access means there are no exclusive rights, while common property mean exclusive group property.[3] Common property has a rich history in wildlife governance (e.g., Ostrom 1990) and is the regime

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[3] Gordon (1954) and Hardin (1968) were, in fact, discussing open access but used the term 'common property' but the work of Ostrom (1990) noted that the term common property or commons had ancient use to mean property held by a well-defined group. This distinction between open access was highlighted by Lueck and Miceli (2007) and is used here.

that best fits wildlife governed by hunter-gatherer societies.   Private property can include a mix

of exclusive property owned by individuals or private organizations.[4] State property is perhaps

the most complex and can be administered in various ways that might mimic private ownership,

common property, or open access.

   To start, in section 2, I present an economic framework for considering different governance

regimes for both the wild stocks and the habitat they require.   In section 3, I present a series of

cases -- focused especially on bison and caribou -- that show the range of governance regimes

that have been used and how those governance regimes depend on history and on law.[5]   Section

4 is a short conclusion.

2.   GOVERNANCE OF HABITAT (LAND) AND POPULATIONS

   The governance of wildlife requires analysis of the governance of land (i.e., wildlife

habitat) and governance of wildlife populations. I begin by economically distinguishing wild

from domestic animals and review basic bioeconomic models of harvest and use of wild

populations.   I then develop a general framework for examining landscape assets such as

wildlife and then focus on the particular governance regimes that predominate.

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[4] Note that common property and private property might become blurred in the case where a private owner becomes
a large organization.   In Ostrom's (1990) work common property typically referred to group property with
relatively informal internal governance and often operating outside a formal legal system.
[5] It is apparent that under the zero transaction costs Coase Theorem any wildlife governance structure would yield
identical outcomes.   Indeed, the evidence presented here implies that transaction costs are substantial and lead to
wide variation in wildlife governance and wildlife allocation.

A. Some Basic Economics of Wildlife

Wild animals can be distinguished from domestic animals by examining the property rights associated with various species (Lueck 1989). This distinction focuses on ownership as a key to understanding wildlife institutions and therefore the size and sustainability of these populations. A population or stock of animals is completely wild only when there exists open access. A stock is fully domestic only when property rights to the stock are perfectly defined and enforced. Ownership can take place over populations (e.g., a herd of deer) or over individuals (e.g., a trained tiger), though the focus here is on ownership of populations and other aggregations of individuals.

One can also consider wild versus domestic in terms of the animals' habitat and behavior.[6] The more natural the habitat, the more wild the animals are. In everyday usage "wild" has implications about ownership and habitat. It also follows that ownership affects animal behavior (and ultimately biology) by altering the natural parameters faced by the animals. It is also true that humans affect the population even without ownership, because open access exploitation can lead to over harvest and other impacts.

The net value of a wild population depends on the gross value it generates and by the costs of generating them. A stock of wildlife is valued for products derived from its carcass, which requires killing individuals, and for services derived from living animals, including ecosystem services. Costs arise, in the form of damage to other resources, because animals consume resources in their day-to-day lives. Ducks and geese feast on small grains, elk and deer forage in hay fields, and

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[6] There are often important, but subtle, biological factors that influence the cost of ownership of animals. For example, Indian elephants have been domesticated but African elephants have not. See also Zuener (1963), Sauer (1953), and Clutton – Brock (1981) on the domestication of wild populations, and the recent study of fox domestication in Siberia (Dugatkin and Trut 2017).

mountain lions attack sheep, pets and even people.[7]

Animal products such as feathers, flesh, hides, and pelts are valuable commodities for which well-established markets often exist. For a market transaction to occur, property rights to at least some of the attributes of the commodity must be well specified, as is true for meat, hides, and pelts. Live animals are valuable because, not only can they provide these products at a future date, but during their lifetime they periodically provide antlers, manure, power, and wool, and they can also produce aesthetic value from activities like viewing or photographing or simply from "existence." Wild populations also can potentially provide a wide variety of ecosystem services.

B.   Governance Regimes and Wildlife Exploitation

Wildlife populations are renewable biological resources and some basic elements of population dynamics are important for understanding wildlife economics and governance Panel A of Figure 1 shows the basics features of biological growth. A population tends to grow slowly at first, then it grows rapidly before ultimately slowing down as it reaches its maximum level or its "carrying capacity" (routinely labeled K) for a given habitat.[8]   The panel plots the size of the population against the rate of growth of the population, showing there is no growth when the stock is zero or at the carrying capacity.

Figure 1

When the population growth rate is largest (A), it is said to be at "maximum sustainable yield" level, or MSY. This means that at that population (X^{MSY}) the largest possible level of harvest could indefinitely be sustained because growth would exactly offset it. At a carrying capacity, however,

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[7] For a example, a mountain biker was stalked and killed by a mountain lion near North Bend, WA. See, "1 bicyclist dead, 1 hurt in cougar attack near Snoqualmie," *Seattle Times*, May 19, 2018.
[8] A more real and more complex population model would incorporate uncertainty.

the sustainable harvest is zero since the net growth rate is also zero. Thus, the simple features of biological growth indicate that population levels must be reduced from carrying capacity in order to increase sustainable harvest.

The economic problem is to determine the optimal level of harvest. Property rights are important in determining effort, harvest (or preservation), stock size, and wealth generated from the stock. If secure property rights to a population exist, the typical outcome is for the owner to harvest an entire cohort at the same time and then restock the habitat with another population.[9] For wildlife the issue is the level of harvest in a period, such as a year or a season.[10] This kind of regime can be found in situations where populations are owned, or where there is open access. If property rights are secure the owner will choose the optimal amount of harvest each period.[11] The bottom panel of Figure 1 uses the biological production process shown in the top panel Figure 1 and couples it with market prices and costs of harvest to generate harvest outcomes under various property regimes.[12] The horizontal axis measures harvest effort (e.g., labor, equipment) and the vertical axis measure the revenues and costs of effort in dollars. The total revenue (*TR*) curve denotes the market value from exerting various levels of effort that yields a harvest (e.g., bison meat) that can be sold in a competitive market. The horizontal axis also shows that the wildlife stock size is directly and inversely linked to harvest effort. When there is no effort the stock is at carrying capacity and declines as effort increase. Under private ownership of the stock the owner will choose the optimal level of effort *E** and earn a

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[9] This is what economists call an optimal timing problem and is the framework that describes everything from timber cutting to grain harvest. This would be the case for domestic cattle as well as for aquaculture. In addition to this, strong property rights also give the owner a strong incentive to invest in habitat (changing *K*) or changing population dynamics (e.g., growth rates) themselves through animal husbandry (e.g., selective breeding, medicine).
[10] Of course, the optimal number need not be constant over time as conditions change.
[11] This would include cases in which the population provided public goods because perfect property rights would still allow the owner to exclude.
[12] This model is explained in detail in Conrad (2010).

periodic rent from this management.[13] Under private ownership the total value of the stock will be the discounted present value of this stream of rents.

Under open access, the level of harvest will be excessive because each user does not bear the cost of their harvest on the size or productivity of the population.[14] Effort will be exerted to E^{oa} which is in excess of E^*. If the marginal harvest costs are low, open access can lead to extreme reductions in population and even extinction.[15] Indeed, open access exploitation is a dominant cause of the many dramatic population reductions and extinctions. In addition, the rent (and its present value equivalent) will be dissipated in the process of overexploitation. Thus, not only is the wildlife resource damaged but little or no economic value is generated from its presence.

As Ostrom (1990) noted common property regimes can generate rents by reducing open access harvest levels. In a wildlife harvest model, common property wildlife exploitation can lead to intermediate levels of effort and the elimination of open access rent dissipation (Caputo and Lueck 2003). As Figure 1, panel B shows, if effort is between E^* and E^{oa} then positive rents will be generated, and the stock size will be larger than under open access. This model can be used to approximate the implicit property rights held by hunter-gatherer peoples around the world.[16]

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[13] The rent will be the revenue less the costs at the optimal level of effort, or *TR(E*) – TC(E*)*.

[14] Another possible case of suboptimal use occurs when investment is required for harvest; in this case an open access regime can lead to under-exploitation. This has been a problem in oil production but has not been the case in wildlife exploitation (Bohn and Deacon 2000).

[15] It is not essential that $X = 0$ when the growth rate is zero; there may be a "minimum viable stock size" required to ensure positive growth rates, which makes extinction more likely. Note, however, that extinction of a single stock is not the same as biological extinction of a species, which is composed of many stocks.

[16] When non-consumptive values (i.e., values from the living stock not harvest) dominate, a private owner may optimally choose to limit harvest or to not harvest at all. However, because many such uses (e.g., viewing, scientific research) are public goods a private owner will have to overcome free-riding problems and this may depend on the owner's ability to enforce his property right

C.   Property Rights to Land and Wildlife

The property rights regimes that govern wildlife are intimately linked to property rights to land and in general ownership patterns of land do not coincide with the habitat requirements of wildlife populations.[17] In modern societies land ownership patterns tend not to be determined by wildlife use but rather by such uses as agriculture (e.g., farms, ranches), mining, and commercial forestry. If a wildlife population were the only valuable resource tied to a parcel of land, then the value of the land would be maximized when land ownership coincided with the population's territory. In this situation a landowner would implicitly own the wildlife population and have incentive to maximize its value by choosing the optimal level of use and population size. In this case wildlife would be quite similar economically to domestic animals, although the habitat would still be "natural." In the usual case, however, wildlife is not the only valued use of land and the analysis is not so straightforward.

Figure 2 shows two possible scenarios that illustrate the fundamental issues. Both panels show a square piece of land that encompasses a circular area of wildlife habitat. For simplicity assume the wildlife equally uses all portions of the habitat. In the left panel (A), there is a single landowner. In the right panel (B) there are 17 different landowners with tracts of various sizes. It is easy to see that in panel A the landowner accrues all costs and benefits that come from the wildlife (except for non-local values, such as existence value). In panel (B), however, no single landowner faces the full costs and benefits, each will have an incentive to harvest animals that occupy their own tracts before they move on and no one will have a strong incentive to invest in habitat improvement or enforcement.

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[17]   The problem of game ownership is analytically similar to other large landscape scale resources such as oil and gas reservoirs or groundwater basins.

Figure 2

Sometimes wildlife values dominate agricultural and other land use values and determine the ownership pattern of land (e.g., aboriginal hunting grounds, a wildlife refuge). If wildlife is the most valued attribute of the land, the wildlife manager would be the most efficient landowner.   A similar case describes the governing property rights for many aboriginal hunting and gathering societies.   In such cases, property rights were designed to protect valuable wild populations which required greater territories than did agriculture.   As discussed below, for example, the bison hunting tribes of the Great Plains defined their property rights to land largely in terms of expansive bison habitat.

In principle the landowners can contract to jointly manage the wildlife, thus solving the problem of how to establish ownership to wildlife populations whose habitat encompasses many landowners.   The ability of landowners to establish rights to wildlife on their property depends on the incentive they have to resolve the conflict between the territorial requirements of a wild population and the optimal tract size of land used for other purposes.   Generally, it is more likely that private landowners will find it in their interest to assert rights to wildlife where wildlife values are highest, where the land is more productive (or of a better quality) for wildlife, where land holdings are large, and where the territorial requirement of wildlife are small.   Accordingly, where these conditions are not met it is more likely that governments will assert control over wildlife.

D.   **Governing Landscape Assets**

The wildlife contracting problem is an example of a more general problem of governing landscape assets (Bradshaw and Lueck 2015).   Oil-gas reservoirs and groundwater aquifers are landscape assets that often lie under many small and heterogeneous surface rights holders. Airsheds, watershed, and viewsheds, like wildlife stocks, are landscape assets that overlie surface

holdings. History and law can generate different governance regimes for such landscape assets, including wildlife.

A starting point is a natural 'landscape' that is unowned and (mostly) unused. The landscape might be an asset such as wildlife habitat, a watershed, a canyon, or even underground assets such as groundwater or an oil reservoir. The landscape is 'large' in the sense the area within the landscape can potentially be used for other assets that would require a much smaller scale of control. For example, the landscape might be an isolated mountain range that could also be used for cattle grazing in relatively small ranches.   It might also be a floodplain potentially used by hundreds of small farmers. The framework incorporates a variety of observed governance regimes including: a) sole ownership of the landscape by a private party; b) cooperative landscape control by private owners of small scale assets; c) small scale landowner's contract with an agent to manage the landscape; d) state control of the landscape with retention of private control of the small scale assets;[18] e) mixed control of the landscape by state and private parties; and f) state control of the landscape and both the large and small scale assets.[19]

The landscape of size (acres) *L* has two assets: *s* is a "small" scale asset (e.g., farmland), *l* is a 'large' scale asset (e.g., wildlife habitat) whose acreage is exactly *L*. The total value of the landscape depends on the value of output from two assets; that is $V=V(s,l)$.[20] This net value will depend on the path of ownership and how the law structures that path.

Figure 3 summarizes the pathways of contracting and the ways in which history and law can affect outcomes. The two paths depend on the relative value of the two assets that comprise the landscape – the landscape-level assets (e.g., the bison habitat) and the small-scale assets (e.g.,

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[18] This control might come through laws, servitudes or regulations.
[19] I ignore such complications as a landscape with more than two assets, uncertainty about the size or location of the landscape, or heterogeneity within the landscape.
[20] If there are two assets but they have the same scale, then the landscape 'problem' vanishes.

farms and ranches). The upper path shows how ownership is initially established at the landscape-level and the lower path shows that ownership is initially established at the small-scale level.

As the figure shows, the natural starting point is a natural area of size L with two assets, s and l, and three stages of ownership. In Stage 1 the decision is to either establish property rights to the small-scale asset (lower path) or to leave the entire area as open access (upper path).   The decision to demarcate would depend on the value of the land in the small-scale use (Libecap and Lueck 2011). The open access path is the default case in which no human property institutions are created.

Figure 3

From each of these two nodes there are two possible paths in Stage 2, both of which assume the large-scale asset becomes more valuable.   The upper path from the open access node is the case in which an initial large-scale claim (size l) is made effectively establishing ownership of the entire landscape,[21] while the lower path is the case in which the landscape remains open access because claiming is too costly.   This can result in overuse as in the fisheries or wildlife harvest case or underuse as in the case in which investment is important (Bohn and Deacon 2000).   The figure also shows the potential for private contractual control or for state or regulatory control to emerge out.[22]

There are also two paths from the small-scale asset demarcation node.   The upper path indicates successful contracting among the small-scale parties to control the large-scale asset. The lower path indicates contractual failure among these parties, so that the large-scale asset

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[21] I ignore the issue of small scale assets within this landscape.
[22] Libecap (1990) discusses this process.

effectively remains an open access resource. The figure also shows the potential for state or regulatory control to emerge out of contractual failures.

The path taken and their outcomes will depend on the costs and benefits of private contracting and on the costs of enforcing claims at difference scales. The benefits will depend on the values of the two assets. The costs will depend on the number of small-scale parties that have right to the larger landscape (*s/L*) and on the legal rules that govern the contracting process. Legal rules can potential affect these outcomes by initiating the choice of demarcation, by affecting the size and types of parcels, and by explicitly structuring the rule for private contracting.[23]

3. CASE STUDIES IN WILDLIFE GOVERNANCE

This section examines several cases of wildlife governance that rely on the above framework.[24] The case studies show a range of governance regimes and show the path of history for those regimes as well. I focus on governance of bison and caribou, two large iconic mammals that have inhabited the northern hemisphere for millennia.

A.   England versus America

Comparing England and America shows how history and the natural landscape features can influence wildlife governance. The ecological character of wildlife and the pattern of land ownership in Great Britain and the United States were distinct during the crucial period of the 1800s when wildlife institutions in both countries were solidifying (Lueck 1989). Private landholdings in the

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[23] Compulsory unitization statutes are an example of law that lowers the costs of contracting among small-scale asset owners to create ownership of the large-scale asset.
[24] Bradshaw and Lueck (2015) use this framework to examine a wide range of natural resources.

United States in the 1800s were small and scattered. In England, landholdings were relatively large and concentrated, and the government held little land (Lueck 1989).[25]

The wildlife stocks that inhabit the two countries also differ in important respects. For example, North American waterfowl typically nest during the summer in Alaska and northern Canada, migrating to Mexico and the southern states for the winter. By contrast, most British waterfowl are not migratory, even though the types of species present are nearly identical. North America is inhabited by many relatively large wide-ranging herbivores, such as bison, deer, elk, moose, mountain goat, and pronghorn antelope; and by carnivores, such as bear, cougar, coyote, and wolf -- all of which require rather large territories. Except for the red deer, wide-ranging herbivores and carnivores are not currently present in Great Britain. Many of the large mammalian species native to Great Britain (and the rest of Europe) became extinct before modern nations emerged.

American wildlife law, which frames management institutions, has origins in English common law, but for wildlife, present-day American and English law differ sharply (Lueck 1989). In the United States, the law places most control of wildlife in the hands of government, primarily the states. In Great Britain, the law places dominant control in the hands of private landowners.

By the mid-nineteenth Century, however, American law was distinct from its English origins (Bean 1983, Lueck 1998, Lund 1980). Property rights institutions among American Indians during this period were largely replaced by state restrictions on takings (or harvest) which began in the early 1800s. The earliest state controls simply restricted the time of year during which it was legal to kill game. When these restrictions were contested, numerous court decisions bolstered the states' authority to regulate the taking and trading of wildlife (Lueck 1998). Courts consistently upheld state wildlife regulations.[26]

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[25] The rationale for the US system is discussed in detail by Lueck (1989, 1991) and Lueck and Parker (2018)

[26] See, for example, *Geer v. Connecticut*, 161 U.S. 519 (1896).

Today, states have the dominant regulatory authority over wildlife control and use, typically vested in a state "fish and game" or "wildlife" agency (Lund 1980 and Tober 1989). The key components of modern game laws and regulations, administered and enforced by game departments, include seasonal restrictions (and sometimes prohibitions) on taking wildlife, prohibition or severe restrictions on game trade, licensing requirements for legal taking of game, and restrictions on the methods by which animals can be taken. Game departments also administer state wildlife refuges and undertake research (e.g. population surveys, re-stocking programs).

The assignments of property rights to wildlife in England and the United States reflect the disparity in land ownership and wildlife ecology between the two countries.[27] During the nineteenth and twentieth centuries, English landowners have had a comparative advantage in wildlife ownership not found in the United States.

B. Wildlife and Native Americans

American Indian tribes specified rights to live wildlife stocks by protecting hunting and fishing territories. The ownership of game among Native Americans had an uncanny resemblance to current American institutions. Indian tribal societies, much like state agencies, controlled wildlife stocks by enforcing the rights to hunting and fishing territories and restricting the time and method of harvest by tribal members.[28] Most often, rights to game were held as "common property" among members of relatively small tribal units. Bailey (1992) finds similar arrangements for tribal groups outside of North America. Native Americans found it difficult, if not impossible, to enforce their property rights to these regions as whites introduced agriculture and

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[27] The regulation of fisheries in the two countries is also supportive. In America, the government generally controls fisheries, but state laws ordinarily grant private control of fish in small lakes and private ponds. In Great Britain, however, private fishing rights are very common on the numerous, and rather small, countryside streams. At the same time, the Crown has long controlled the fisheries in open seas, navigable rivers, and the foreshore.

[28] Bailey (1992) finds similar institutions around the world for hunter-gatherer societies.

industry to the New World, causing the relative value of the wildlife attributes of the land to decline drastically (Cronan 1986 and Lund 1980). During this period of open access "market hunting" flourished and many wildlife populations in the United States plummeted.[29] There were well-established rights and markets for game products such as meat and hides, but rights to live wildlife stocks were practically nonexistent (Tober 1981). Today Native Americans have jurisdiction over wildlife on their reservation lands and there is wide variation in outcomes: some governed as near open access while some generate revenues.

C.   Bison and Caribou

Bison bison, the American Bison, is a large herbivore also known as the buffalo. Before European colonization of North America there may have been 30 million of more bison, but by 1900 they had been reduced to approximately 1,000 animals.[30] Since that time bison populations have increased to over one-half million animals inhabiting national parks and refuges, Indian reservations, and private lands. In general, they are governed by state laws that cover domestic livestock, so they are not typically treated as wildlife and under the purview of state wildlife agencies. *Rangifer tarandus*, called caribou in North America and reindeer in Europe, is a medium size deer that inhabits the northern reaches of the Northern Hemisphere.[31] *Rangifer* has been domesticated to various degrees in Europe and governed by pastoral societies, including the Sami people in Scandinavia, while in North America *Rangifer* is now primarily governed by state and provincial wildlife laws. Table 1 summarizes the wide range of regimes that have governed these two species.

Table 1

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[29] Lueck (2002) examines the case of the American bison and the open access hide trade that led to its decimation.
[30] The discussion here relies on Lueck (2002).
[31] A good overview is found in Jernsletten and Klokov (2000-2002) and Demarais and Krausman (2000).

Bison: Hunter – Gatherer Governance.   Prior to European settlement of North America, bison and their habitat were governed by institutions best understood as common property regimes by nomadic native American tribes.[32]   While the bison were hunted by village-dwelling tribes as well, because of the nomadic nature of the bison, their hunting was largely done by tribes such as the Sioux or the Crow in the great plains, who would move around with the bison herds. Indeed, tribal organization mirrored that of the bison: small groups in the winter and spring and large groups in the summer and early fall when the bison were also congregated into the massive herds.[33] Before the establishment of robe and hide markets in the 19th century, these tribes hunted the bison for their subsistence.

Bison: The Robe Hunt on the Northern Plains. The establishment of trading posts along the Missouri River and Canadian border facilitated trade between the Native Americans for many wildlife products including bison robes.   From 1820-1880 white traders purchased robes (heavy winter hides) from Indian hunters.   Numerous reporters indicate that robe harvests shipped out of the Upper Missouri region (North Dakota and Montana) averaged between 50,000 and 100,000 robes for nearly 60 years.[34]   This robe market occurred only on the Northern Plains where cold winters led bison to develop the heaviest and most valuable coats. The robe market led to an increase in bison harvest but this short-lived market had little overall impact on bison population and no impact on bison habitat.[35] The robe market can be characterized as being governed by common property for the first 40 or so years and perhaps by open access for the last

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[32] Indians living in the eastern forests were often engaged in agriculture and thus tended to have property rights to land defined over relatively small territories.   In this setting bison population were essentially open access.

[33] Lowie, *supra* note 30, Wissler, *supra* note 30.

[34] Hornaday, *supra* note 1, Isenberg, *supra* note 1, McHugh, *supra* note 29. During this period, there also was always a limited trade in pemmican and tongues (a delicacy to whites and Indians).

[35] This case contrasts with Demsetz (1967) who found the introduction of the beaver hide market changed governance regimes among the Montaigne Indians.

15 years. There were two important features of the robe trade that distinguish it from the hide trade that followed. First, the robe trade occurred mostly during a period (pre 1880s) when the land had no valuable alternative uses, so the carrying capacity of the habitat was not being reduced. Second, the optimal time to hunt bison for robes was only in the late fall and early winter when the robes were prime.[36]

Bison: Open Access Extirpation, 1850 – 1900. American expansion across and into the Great Plains began in earnest after 1850 and tribal governance of habitat and populations eroded quickly effectively creating open access to the bison populations. This occurred even as bison habitat became privatized into relatively small holdings for farms and ranches, much too small to control the territory of bison populations. Railroads and new long-range rifles lowered the cost of access and harvest, and the introduction of the hide market to eastern and European market caused a rapid open access depletion from 1870 to 1885. During this period the exploitation of bison on the Great Plains transitioned generally into the hands of white hunters as most natives were either relocated to reservations or killed in conflicts with the U.S. soldiers and settlers. Still, the last large herd of bison in the great plains was actually wiped out by a Sioux hunting party in 1883 in what is now southwest North Dakota.   By 1890 the bison were nearly extinct, reduced to roughly 1,000 animals at scattered locations, including Yellowstone National Park which was created in 1876 before the last great herds were extirpated. Although direct measures of the extent of rent dissipation are not available, Isenberg's discussion of the hide hunters fate is consistent with open access and rent dissipation: "Euroamericans waged a scorched-earth campaign against the Indians who impeded the expansion of industry. Yet the hide hunters' victory was hollow; when the

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[36] Allen, *supra* note 20, at 59, says November through January are the prime months for robes. Robes were also more costly to prepare than hides.

campaign was over, most of the hunters found themselves no wealthier than before."[37]   This description of bison hide hunting is consistent with open access exploitation by a group of homogeneous hunters with low opportunity costs.[38]

Bison: Private Governance, 1900 – Present.   During the period of the open access hide market a few private ranchers explored the possibility of profitably raising bison.   Charles Goodnight had captured three calves to start a herd in 1866 in Texas, William and Charles Alloway captured three calves, and James McKay captured five calves, to start herds in Canada between 1872 and 1874. The famous Pablo-Allard Herd began when a Pend d'Oreille Indian named Walking Coyote captured several calves to in central Montana in 1873.   Walking Coyote led the calves back to the Flathead Valley in western Montana where the herd thrived (FWS 2010).   This herd led to the establishment of herds in parks and on ranches during the 20th century.[39]

In 1905 Ernest Baynes and William Hornaday founded the American Bison Society, setting in motion the eventual appropriation of federal funding to establish parks and refuges to protect and grow bison populations (Lueck 2002).   The American Bison Society acted as an appropriation group for purchasing bison and donating them to herds on public lands, such as the National Bison Range in western Montana, not far from where the Pablo-Allard herd once thrived.   After these public herds grew, the American Bison Society voted to disband in 1935

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[37] Isenberg (2000), at 163. There was also a small market for meat by for railroad workers and settlers (for example William "Buffalo Bill" Cody became famous as a hunter hired by Kansas Pacific in 1867 and killed 4,280 bison; see Hornaday, *supra* note 1, at 478.) but this had little effect beyond the travel corridors.   For example, Hornaday (1889) cites Dodge as settlers killing just 1500,00 compared to 3.7 million killed in 1870-74 for hides.   During the hide trade there was a limited amount of meat shipped east but it was generally too costly to transport from a kill site to the railroad.   After 1872, small amounts were shipped in refrigerated cars.

[38] Hill (2014) argues that while bison were harvested under open access there was little rent dissipation.

[39] At this time, the Pablo-Allard herd was one of the largest private herds, totaling 800 animals by 1908 (FWS 2010).   Many regulations before 1900 meant to conserve bison or their harvest often came too late, often after extirpation on the state level.   In 1864, the Idaho legislature enacting laws protecting the bison, however bison no longer existed in the state (FWS 2010).

and the bison on public lands were placed under the arm of various federal agencies, such as the Fishing and Wildlife Service or the National Park Service (FWS 2010).

Because the bison populations in most states were at or around zero, bison were not governed by the new state wildlife laws that emerged in the late 19th and early 20th centuries (Williams 1939).   Outside of Yellowstone National Park, bison were on private lands and were thus governed by the law of domestic livestock, like cattle, sheep and pigs.   Bison could be bought and sold and transported like cattle and owners had the same rights, duties, and obligations as cattle owners.   Under this legal regime the increase in size of public herds was matched additionally by an increase in the size of private bison herds.   Of the approximate 500,000 bison now inhabiting North America, the vast large majority are privately owned and inhabit private lands in the U.S. and Canada.   Native Americans have also In recent decades some Native American tribes have reestablished bison herds on their reservation lands.

Bison: Yellowstone National Park.   Yellowstone National Park was created in 1876 out of federal lands that were part of the territories of Idaho, Montana, and Wyoming.   The Park is comprised of over 2 million acres of unfenced terrain in the northern Rocky Mountains.   Bison were not widespread in the Yellowstone region, compared to the Great Plains, but there was always bison in the scattered high elevation grasslands.   Largely because of geographic isolation the bison in the Park were not hunted to extinction and today the park herd is the only herd in the U.S. known to be free of domestic cattle DNA.   The Park bison population tends to vary these days from 3,000 to 4,000 from a low of about two dozen in 1900.

The Yellowstone herd is an anomaly among private and public herds as they are not fenced and routinely roam outside Park boundaries in the winter to find better grazing on lower elevation lands outside of the park.   These winter range lands are a mosaic of private, state, and

federal lands.[40] The Yellowstone bison carry brucellosis, a bacterial infection that can be transmitted to domestic livestock and can cause abortions, infertility and lowered milk production (APHIS 2007).   The threat of Brucellosis spreading into private livestock herd by intermingling of bison with domestic cattle just outside the park has led to conflicts.

American Prairie Reserve: Private Contracting for Wildlife.   On the plains of north central Montana a new bison governance structure is being created by the American Prairie Reserve (APR). The APR was established in 2001, as a private non-profit organization[41] whose goal is to create a working wildlife preserve on the northern Great Plains in Montana.   The goal of the APR is to create a reserve of 3.5 million acres (about 1.5 times the size of Yellowstone Park) by consolidating private and public land through purchase, leases, and easements.   To date APR has 400,000 acres in its reserve.   In a manner similar to private wildlife operations in South Africa, APR tends to eliminate fencing on its lands to facilitate large scale contiguous prairie habitat.[42] One of the key objectives of the APR is to reduce the number of domestic cattle and maintain a bison population. Bison were reintroduced to the Reserve in 2005 and now number approximately 900.   The APR projects a population of over 10,000 bison by 2030.[43]   The APR represents an example of private contracting to establish wildlife habitat, one that has emerged as the relative value of wildlife has increased. The key to APR's ability to create this reserve is the fact that bison are legally governed as private property, so the APR could buy bison to repopulate the habitat mostly without inference

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[40] The details of current bison management in Yellowstone and the history of bison in the Park can be found at https://www.nps.gov/yell/learn/management/bison-management.htm and at https://www.nps.gov/yell/learn/management/bison-history.htm .
[41] Information is available at https://www.americanprairie.org/building-the-reserve accessed May 27, 2018.
[42] The case of the APR actually mirrors the case of 'wildlife ranching' in South Africa .   The law in South Africa grants private ownership of wild species if they are enclosed.   In the last several decades this has led to a rapid expansion of wild populations on large private holdings (Cousins, Sandler and Evans 2008).
[43] Bison population growth rates can be has high as 20% per year. Yellowstone Park notes its herd has grown 10 to 15% annually for many years.

from the state wildlife agency.[44] Figure 4 shows a recent map of the APR lands and the mosaic of private and public lands within which they operate.

Figure 4

Caribou: Hunter – Gatherer Governance.   The Inuit tribes of northern Alaska and Canada have been subsistence hunters exploiting of the caribou populations native to the tundra, boreal forests, and mountainous landscapes.   While caribou have historically ranged from the west Coast of Alaska to the coast of Newfoundland, the species is not uniformly distributed across this range, with many separate herds.   Indigenous use of caribou was similar from the native plains tribes' use of the bison in that they managed the nomadic herds communally as tribes to harvest. The caribou hunting Inuit tribes of Alaska and Canada were and are not generally contiguous, comprising now of 13 recognized Alaska native corporations and primarily the western subarctic First Nation Governments of Canada as well some groups stretching as far eastward as Quebec. For millennia these tribes adopted nomadic lifestyles to follow the large herds on their annual paths throughout Canada and Alaska, such as the western subarctic tribes in Canada primarily traversing the boreal forests of Yukon and the Northwest Territories or the Iñupiat of Alaska traversing the northwestern tundra (CIER 2013). Unlike their indigenous counterparts in Europe and Asia these people did not domesticate the caribou.

North American Caribou: Modern Agency Management.   With the colonization of the U.S. and Canada the Inuit governance structures gave way to state and provincial controls. In Alaska, the harvest of caribou is managed by the Alaska Department of Fish and Game while in Canada the management is directed by the environmental departments of each respective province,

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[44] APR has, however, faced some resistance from local interests concerned about the changing character of the cattle ranching -based economy.

primarily Yukon, Northwest Territories, Nunavut, and Quebec.[45] Each department regulates

both recreational and subsistence hunting. In Alaska recreational hunting of caribou is managed

by license which are won through lottery while subsistence hunting is purchased as a tier II

permit, for the explicit and restricted purposes of residential subsistence. The Alaskan hunting

season for caribou is generally July through September while in Canada the hunt generally

occurs August through January. It should also be noted that like the contiguous US and all other

provinces of Canada, these caribou hunts also have a system of bag limits. In Alaska, depending

on the zone, bag limits may be as low as one bull per licensed hunter to two caribou of any stock,

while in Yukon, for example, most recreational zones have a limit of one animal.

Porcupine Caribou Herd.   The Porcupine Caribou herd is one of the largest caribou herds in

North America.[46]   The herd ranges in size from 100,000 to 200,000 annually and uses habitat in

Alaska and Canada (shown in Figure 5). The herd migrates between the lands around the Brooks

Range in north central Alaska to the Richardson Mountains in Canada, and their summer calving

grounds are along the Porcupine River.   Indigenous people historically hunted the Porcupine

Herd for subsistence.[47]   Because the herd requires habitat in both the U.S and Canada an

international agreement was signed in 1987, founding the International Porcupine Caribou

Board.   This board consists of four members from both Canada and the US and serves as an

advisory committee to the regulatory agencies in each nation (PCMB, 1985). The habitat of this

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[45] Information on these regulations for hunting and subsistence can be found: Alaska Department of Fish and Game: http://www.adfg.alaska.gov/index.cfm?adfg=hunting.main; Yukon Environmental Department: http://www.env.gov.yk.ca/; Nunavut, http://www.env.gov.yk.ca/animals-habitat/mammals/barrengroundcaribou.php; Northwest Territories https://gov.nu.ca/environment/information/species-management; Quebec https://mffp.gouv.qc.ca/the-wildlife/hunting-fishing-trapping/?lang=en; and Newfoundland http://www.flr.gov.nl.ca/wildlife/caribou.html.
[46] See http://www.pcmb.ca/herd
[47] The Gwich'in people of Canada was one of the traditionally nomadic tribes hunting the Porcupine caribou the longest.   The ceased nomadism in 1870 to seek permanent settlement (ADFG 2018).

herd can generally be described as a mosaic of private and public lands, predominantly the Arctic

National Wildlife Refuge. The harvest of the Porcupine herd follows the same regulatory

oversite as most other herds.   The dominant governing bodies are the Alaska Department of Fish

and Game and the Yukon Environmental Department, whose management structures have been

discussed.

The Sami Reindeer Culture. The Sami people of northern Europe are the indigenous people of

the Scandinavian peninsula, Finland and the Kola peninsula of Russia. Before the 15th century

the Saami people were primarily a semi-nomadic subsistence hunting culture until the 16th

century when some began herding reindeer in response to assimilation and taxation by these four

countries.[48] The traditional Sami system for reindeer husbandry was the *siida* system.   This

system was a demarcation system as well as a management system as it was a communal

agreement of several families to have individual rights to their respective resources but operate

their reindeer herds communally (Jernsletten and Klokov 2002). The Sami herders remained as

semi-nomadic groups, moving with their marked reindeer across lichen rich pastures.

Technological advancements of the mid-20th century helped ease the burden of such a lifestyle

such as the introduction of the snowmobile for example.   Given the nomadic nature of the

reindeer and Saami themselves, traversing the habitat was largely done with skis prior, however

snowmobiles allowed Sami to traverse the winter landscape in northern Norway more efficiently

(ICR, 2014).

Norwegian Pasture Management.   The current regime of Norwegian reindeer governance

began in 1976 with the passing of the Norwegian Reindeer Herding Act which gives the Sami

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[48] Larsson (2017) examines the Sami history in detail.

the exclusive right to manage reindeer in six distinct pasture areas of Norway while designated "non-Sami" parties were allowed to herd in concession areas of southern Norway. Currently there are approximately 3,000 people actively herding reindeer in Norway across 140,000 square kilometers of the country. Under the modern system, herds are still technically a part of a *siida* however the "husbandry unit" or driftsenhet[49], taking the form of a license or legal ownership agreement, is owned only by a single person or shared amongst spouses. The husbandry units lie within districts that partition grazing lands which are enforced by the district committee. Above the district committee is the Area board which grants requests to move herds throughout the pasture area as well as determine grazing times and comment on municipal development plans. Beyond the pasture areas the drafting of reindeer husbandry policy is in the purview of the Ministry of Agriculture's Reindeer husbandry office, while the execution of their policy and day-to-day functions belong to the Norwegian Reindeer Husbandry Board (Jernsletten and Klokov 2002). As of 2007 within each pasture area there are 82 districts[50] in the Saami owned territories, and the primary responsibilities delegated to the district committees are containment and separation of herds in the district (Ministry of Agriculture and Food 2015).

Norwegian Wild Reindeer. In Norway, there are also sizeable populations of (non-domesticated) wild reindeer. In an analogous manner of governance to semi-domesticated reindeer, wild reindeer lands are partitioned into 23 distinct wildlife areas,[51] however these wild herds generally traverse private and public lands. The herds are managed by municipal boards that

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[49] There has been conflict with the current agency led system of husbandry. In 1978 a committee of the Norwegian Legislature proposed a termination of the Husbandry Act and a return to the Saami traditional siida system (Jernsletten and Klokov 2002).

[50] The total of 82 districts was a revision in the 2007. The original legislation from 1976 established 90 districts in each pasture area (Jernsletten and Klokov 2002).

[51] The largest wild herd resides in Hardangervidda, totaling around 10,000 wild animals, of the estimated 25,000 total wild reindeer in Norway (Norsk Villreinsenter, 2017).

report to the national district committees under the national environmental directorate. Most use

of wild reindeer is through organized hunts or for recreational spotting. The wild reindeer on the

island of Svalbard (also known as Spitzbergen) are managed similarly to those on the Norwegian

mainland, in that ownership of the wildlife stocks is either between those hunting them as game,

or government ownership. Unlike on the mainland however the Svalbard animals are not split

by regional differences or governed by committee. The day-to-day management of wild

reindeer is under the office of Svalbard's governor, who, on those matters, reports to the

environmental directorate in Oslo, as opposed to a district committee (Norsk Villreinsenter,

2017).

Reindeer Peoples in Russia. The habitat for *Rangifer* is circumpolar so it is not surprising that

reindeer peoples are found in Russia. Indeed, reindeer husbandry is more prominent in Russia

than anywhere else in the world, where approximately two thirds of the world's stock of

domesticated reindeer exist in Russia (Jernsletten and Klokov 2002). Unlike Norway or other

Scandinavian countries, reindeer husbandry is not the right of the sixteen indigenous groups who

have historically herded reindeer in Russia.[52] The ownership of reindeer in Russia falls into one

of three categories: state, public or private ownership. State ownership purely consists of those

reindeer herded for agricultural research, an experiment driven ownership. Public ownership is

the category in which most reindeer would fall under, where the animals are owned by collective

state farms operated by a public enterprise. Private ownership is generally individually or

communally owned reindeer by clans. The difficulty in determining private ownership is that

many individual owners of reindeer work and herd reindeer for public enterprises, so their

privately-owned reindeer are herded together with publicly held animals. Further confusion

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[52]   It should be noted, according to Jernsletten and Klokov in 2002, the only groups actively engaging in reindeer
husbandry in Russia were indigenous people.

arises in that there is little discrepancy between state and publicly owned reindeer, as the only differing factor in their management are the uses of the resource and not who owns them. The difficulty of differentiating public and private ownership does however ease the question of who owns and manages the habitat, and that would be predominantly public enterprises and the agricultural regulatory system of Russia.

Historically the management of reindeer performed in indigenous Russian collectives only consisted of 20 to 100 individuals, however under the public enterprise management system there exists an entire "herding brigade" per herd owned by the enterprise (Jernsletten and Klokov 2002). There are often bureaucratic conflicts on the local and federal level over husbandry in the Russian system. One example given by Jernsletten and Klokov (2002) is that the Department of Agriculture oversees management for the local Okrug Administration, or area administration, of the Yamal-Nenets, while the State Committee Administration of Land-Use manages the pastures, who all deal directly with public enterprises, but do not work with private owners of reindeer. This effectively meaning that in the Yamal-Nenets region there is no regulatory arm or management body controlling private husbandry.[53] There has been a steady decline in the number domesticated reindeer in Russia now estimated to be about 1.2 million animals.[54]

D.   Migratory Waterfowl: Biological and Administrative Flyways

In North America there are vast populations of migratory birds that require continental swaths of habitat as they move north and south in their annual migrations. Known collectively as 'migratory

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[53] This is primarily an issue in the tundra, while in the taiga husbandry is a smaller resource with respect to the peoples' overall subsistence.
[54] The Russian reindeer population was recently near twice this size. This decline in population size is most noticeable in the northeastern zone of Russia where there are communities in which herding is vanishing in its entirety (Jernsletten and Klokov 2002)

waterfowl,' these birds nest in the northern reaches of the continent during the long summer days and spend winter in the mild southern reaches of the continent. These birds primarily belong to the family *Anatidae* (ducks, geese, brant, and swans) but also include other migratory species.[55]   In their biannual migrations, North American waterfowl populations use "flyways" which support distinct populations and their control roughly corresponds with this distinction. Biologists have divided the continent into four north-south flyways that comprise these habitats: Pacific Flyway, Central Flyway, Mississippi Flyway, and the Atlantic Flyway. These four flyways are shown in Panel A of Figure 5.

Figure 5

As is clear from the figure, these populations utilize a massive landscape stretching thousands of mile, across many states and provinces in Canada, Mexico and the U.S. The ownership of this landscape is a mosaic of public and private land in tracts ranging from national parks to small residential lots. In the 19th century, populations were subject to open access exploitation in a manner described in bottom pathway in Figure 3. During this period and in the early 20th century this led to dramatic reduction of these populations as hunters supplied meat and feathers to wildlife markets. Given the enormous number of landowners a private contractual solution was not feasible, nor was a state-based regulatory solution. In 1916 the US and Great Britain (on behalf of Canada) entered into a treaty to protect migratory birds.[56]   As a result of this treaty, the regulation of migratory waterfowl hunting is guided by several Flyway Councils composed of agencies from the appropriate states and provinces. Figure 6 shows maps of both biological and administrative flyways.

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[55] Additional species include: *Rallidae* (rails, gallinules, and coots) *Gruidae* (cranes) *Charadriidae* (plovers and lapwings) *Haematopodidae* (oystercatchers) *Recurvirostridae* (stilts and avocets) *Scolopacidae* (sandpipers, phalaropes, and allies) *Columbidae* (pigeons and doves).

[56] Convention for the Protection of Migratory Birds, Aug. 16, 1916, United States-Great Britain (on behalf of Canada), 39 Stat. 1702, T.S. No. 628.

Figure 6

4. CONCLUSION

The conservation and management of wildlife continues to be an important issue in environmental policy. Debates about markets, landowner's rights, and the role of government are ongoing and often contentious. The comparative institutions approach to wildlife governance recognizes the wild variation in wildlife institutions and the role of history and law in determining these institutions. History is important because it sets a structure for ownership of land (habitat). Imperfect incentives will always exist and so will difficult institutional "border" problems. Increasing relative wildlife value will put pressure on old institutions to change. ets, populations & land use is not well understood.

The comparative institutions approach to wildlife governance relies on an examination of the property rights to the habitat and the stocks of wild populations. The approach recognizes the often-extreme costs of delineation and enforcement of property rights to wild populations and their habitat and thus all systems are notably imperfect compared to the typical neoclassical economics approach. These costs arise because wildlife habitat and wildlife populations are part of the land which has many attributes and uses, most notably for residential and agricultural uses. The organizations that govern wildlife tend to be ridden with transaction costs and imperfect property rights and the most efficient system is one that maximizes the total value of the package less the enforcement and administrative costs. An economic framework is developed for considering different governance regimes for both the wild stocks and the habitat they require. The cases I examine, especially bison and caribou, show the range of governance regimes that have been used and how those governance regimes depend on history and on law

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Table 1: Cases in Wildlife Governance

Bison/Buffalo	Habitat Ownership	Population Ownership	Outcomes
Hunter-Gatherer Governance	Tribal common property.	Tribal common property.	Sustainable subsistence harvest, culture tied to bison.
Northern Plains Robe Hunt	Tribal common property.	Tribal common property.	Sustainable native hunting, trading with whites.
19th Century Open Access	Private and public lands.	Open access with some private herds.	Increased open access. Some livestock.
20th Century – Present	Private lands, Public lands (state/federal), tribal reservations.	Private ranchers, government agencies, tribes (recent).	Bison used as livestock. Some common ownership.
Yellowstone National Park	Public land.	U.S. Federal government.	Limited use, herds managed for conservation.
American Prairie Reserve	Private and public land	Private ownership of bison	???

Caribou/Reindeer	Habitat Ownership	Population Ownership	Outcomes
US-Canada			
Hunter Gatherer pre-white contact	Indigenous tribal common property.	Indigenous tribal common property.	Subsistence hunting. Communally owned wildlife and territory
Agency Management	Native corporations, private lands, public lands (State and national).	Subsistence hunters, state and national governments.	Sustainable herd management.
Porcupine Caribou Herd	Native lands/corporations, private and public lands.	Subsistence hunters, state and national agencies	Sustainable herd management.
Europe			
Sami *Siida*	Sami families	Sami families	Sustainable use.
Pasture Management	Sami in pasture areas, Sami and non-Sami in Concession Zones.	Sami and non-Sami	Common property and private property use mix.
Wild	Public lands, some private land.	Norwegian government	Sustainable management.
Reindeer in Russia	Predominantly public property, some private property.	Predominantly public property, some private property.	Public and private management conflict.
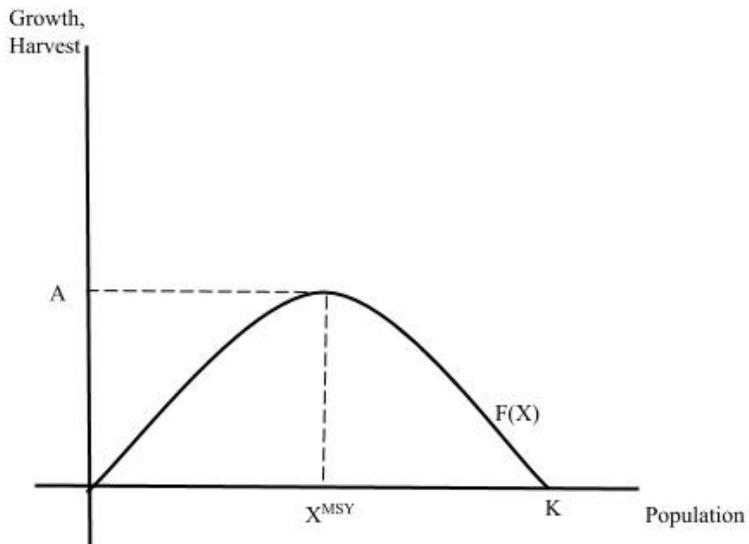
Panel A: Stock-Growth Relationship
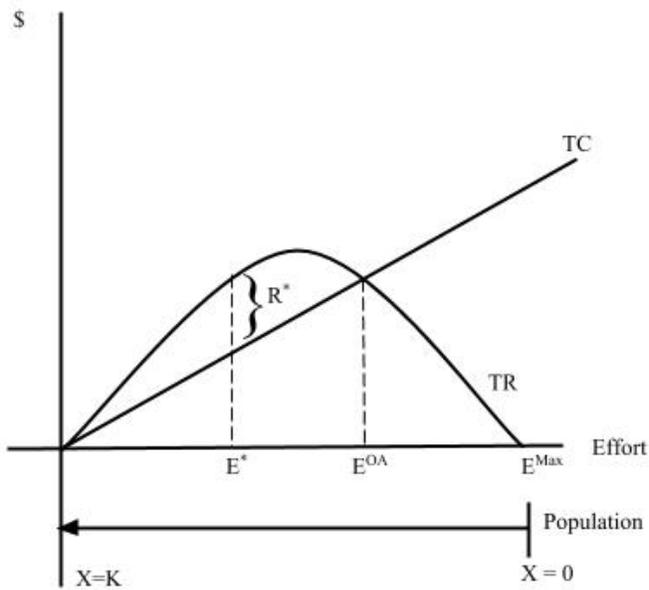
Panel B: Optimal Harvest of Wild Population
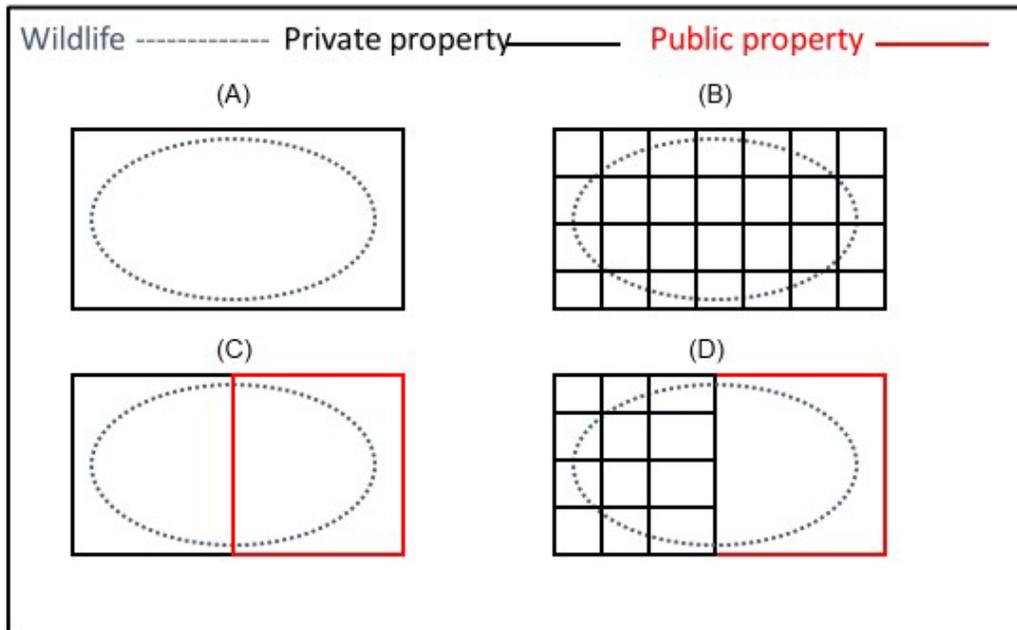
Figure 1: The Biological Production Function

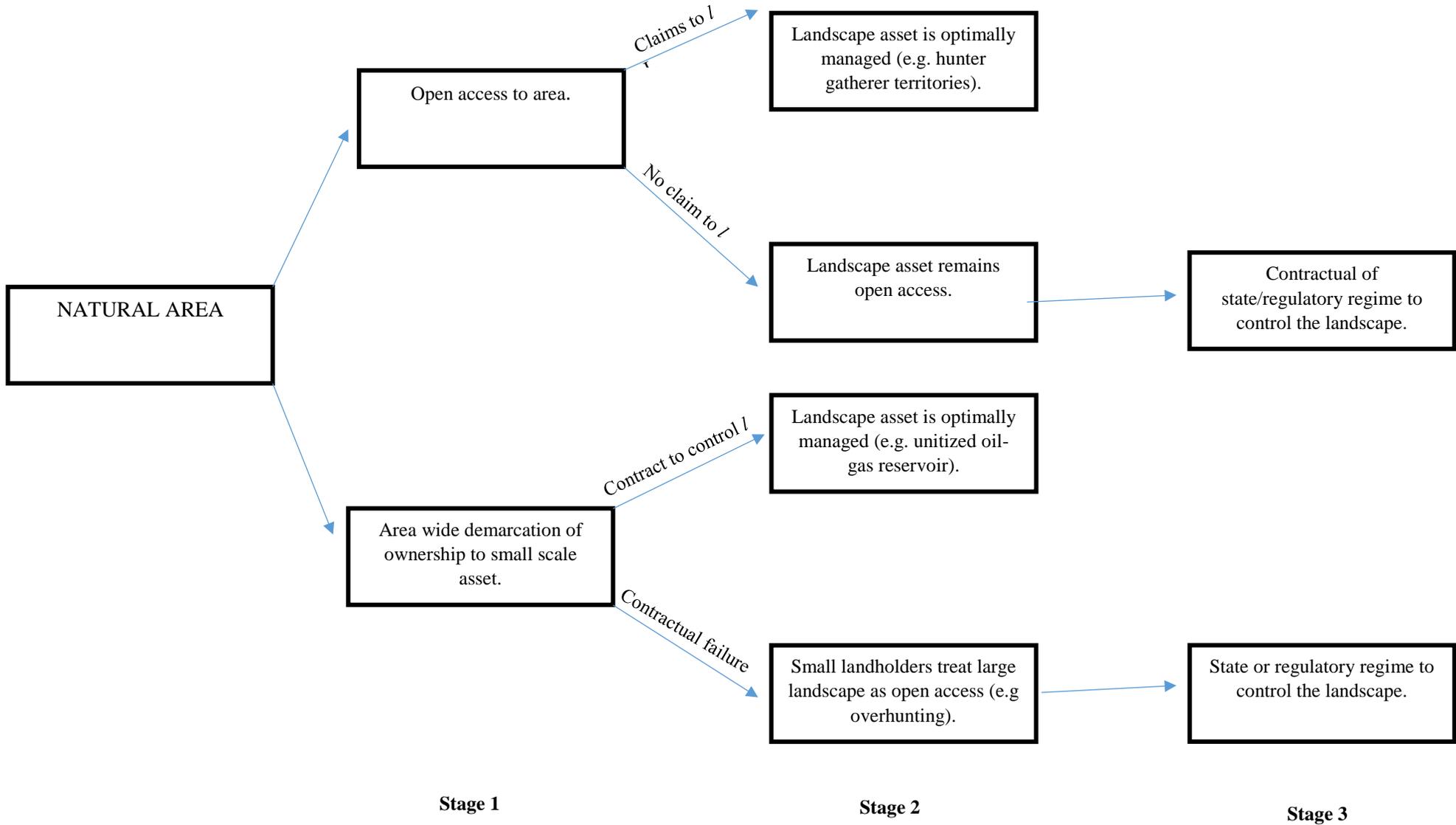**Figure 2: Wildlife Ownership and Landowner Contracting**

Open access to area.

Claims to l → Landscape asset is optimally managed (e.g. hunter gatherer territories).

No claim to l → Landscape asset remains open access. → Contractual of state/regulatory regime to control the landscape.

NATURAL AREA

Area wide demarcation of ownership to small scale asset.

Contract to control l → Landscape asset is optimally managed (e.g. unitized oil-gas reservoir).

Contractual failure → Small landholders treat large landscape as open access (e.g overhunting). → State or regulatory regime to control the landscape.

Stage 1   **Stage 2**   **Stage 3**

Figure 3: Decision Tree for Landscape Control

36
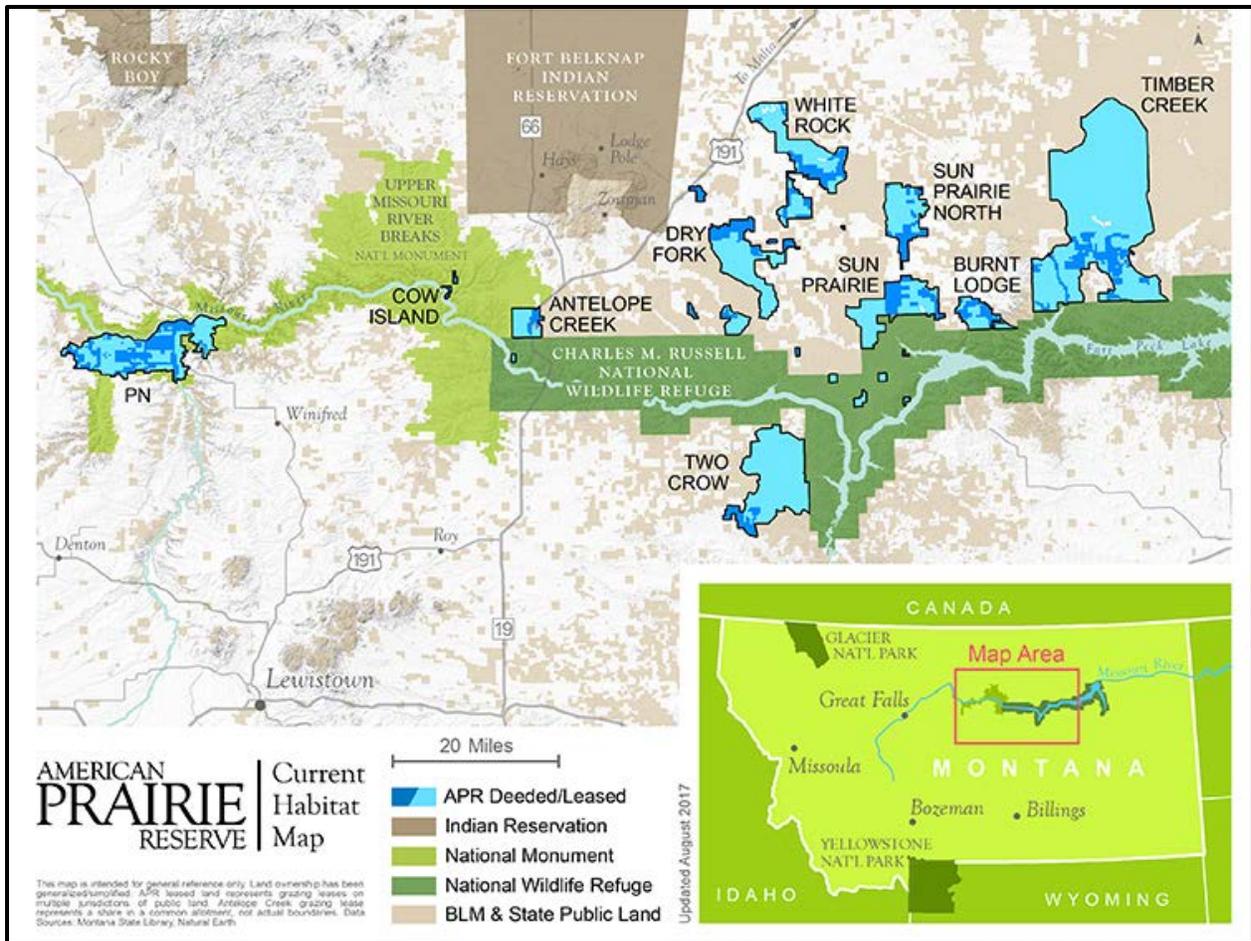
Figure 4: Map of American Prairie Reserve and Surrounding Lands, Montana 2018

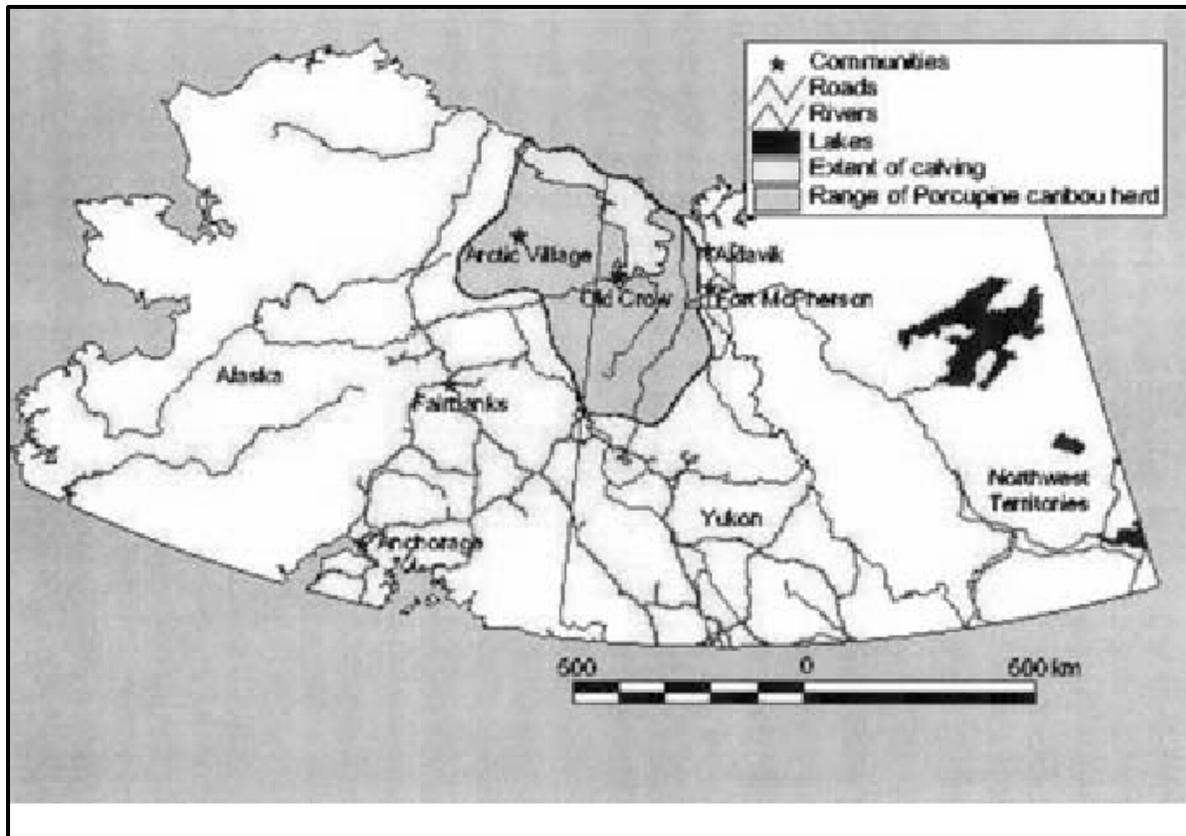Source: https://www.americanprairie.org/building-the-reserve accessed May 17, 2018.

Figure 5: Porcupine Caribou Herd Population Borders

Source: Jack Kruse et al. *Modeling Sustainability of Arctic Communities: An Interdisciplinary Collaboration of Researchers and Local Knowledge Holders* (2004). In Ecosystems 7(8):815-828.
https://www.researchgate.net/figure/Map-of-the-range-of-the-Porcupine-Caribou-Herd-PCH-the-PCH-calving-grounds-and-the_fig1_227074168

Panel A: Biological Flyways
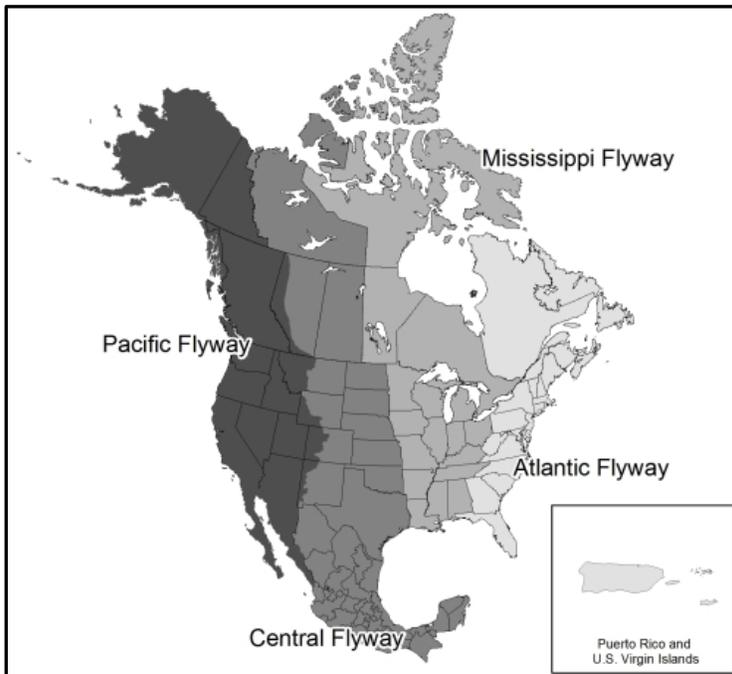
Panel B: Administrative Flyways

Figure 6: Migratory Waterfowl in North America