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A spatial analysis of border "security" and jaguars in the U.S.-Mexico borderlands

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In March 1996, a jaguar *(Panthera onca)* named Border King was seen in Arizona's Peloncillo Mountains, followed by a sighting of a second male, Macho B, in September. The cats had crossed the U.S.-Mexico border and quickly came to symbolize a conservation success story in complicated geopolitical terrain. Two decades later, the Trump Administration's increased militarization of the borderlands prompted concerns about the deleterious impacts of border wall expansion for jaguar movement and survival. This study examines the expansion of border barriers, and potential impact on jaguar habitat. Using geospatial technologies and public data, we measure border barrier expansion between 2005 and 2021. We found that of the suitable jaguar habitat that touched the border in the study area (155 km), 86% (or 133 km) had been cut off by border barrier by 2021. We distinguish "wall" from other barriers, including vehicle barriers, using aerial imagery. Our results show although barriers built from 2006 to 2015 were triple the length of those built under Trump, the majority consisted of vehicle barriers, which animals may be able to cross. Trump era construction shifted vehicle barriers to restrictive walls limiting animal movement. We argue examining the type of barrier is crucial in understanding the potential for border "security" disruption to jaguar movement and futures in the borderlands.

KEYWORDS

jaguar (*Panthera onca*), border, white settler colonialism, geospatial, political ecology

1 Introduction

In March 1996, the first U.S. jaguar[1] sighting in at least a decade occurred in Arizona's Peloncillo Mountains (USFWS, 1997). It was quickly assumed by ecologists and wildlife managers that the jaguar – known as Border King – must have crossed the U.S.-Mexico border (Glenn, 1996). Later that year, a second male jaguar, Macho B, was seen in Arizona's Baboquivari Mountains (McCain and Childs, 2008). The excitement of jaguar presence in

1 *Panthera onca.*

one of the world's most militarized geopolitical boundaries quickly rippled through conservation and ecology worlds, leading to various studies, conservation efforts, and new research funding (Childs, 1998; AZGFD, 2022). After centuries of jaguar hunting and feared elimination in the U.S., many proclaimed jaguar presence in the borderlands[2] a great ecological comeback story (Ceballos et al., 2021; Laird-Benner and Ingram, 2010).

Twenty years after Border King's sighting in a craggy canyon in southern Arizona, Donald Trump was elected as President of the United States following a political campaign that vilified undocumented migrants (Béland, 2020; Alam and Asef, 2020) and pledged to "build the wall" (Finley and Esposito, 2020; Horton, 2021). Ecologists and environmental justice proponents quickly expressed concern about new border wall implications for Indigenous peoples (Tasker, 2019), migrants (Jusionyte, 2018), and wildlife (Wildlands Network, 2021; Greenwald et al., 2017; Mahler, 2016). One environmental organization explained, the border wall, "will have disastrous impacts on our most vulnerable wildlife … including jaguars…" (Greenwald et al., 2017, p.2). Others predicted the wall would have deleterious impacts on both wildlife and Indigenous people in the region (Tasker, 2019; Greenwald et al., 2017). For instance, the Tohono O'odham people would be impacted by the wall, immigration policies *and* impacts to jaguars, which have cultural significance to the tribe (Pavlik, 2003).

Due to recent attention on relationships between border wall and jaguars along the U.S.-Mexico Border, this study examines the expansion of border barriers between 2005 and 2021, across multiple presidential administrations, and potential impacts on jaguar habitat. Our research found multiple types of barriers have been constructed and reconstructed in Arizonan and New Mexican borderlands including wall, vehicle barriers, and fence. We thus use the term "barrier" generally as a catchall category for fence, wall, and other barricades at the border. In the results we discuss the different types of barriers constructed over time, and potential impacts for jaguars.

This study combines geospatial methods and analysis of historic, policy, and other documents. Using geospatial technologies and publicly available data (e.g. data from 2020 census and National Land Cover Database managed by USGS), we mapped suitable jaguar habitat on the U.S. side of the international boundary. We then mapped border barrier expansion between 2005 and 2021, and its relationship to suitable jaguar habitat in the U.S. Before we discuss methods and results, we review literature on white settler colonialism and implications for apex predators, jaguars in the borderlands, and border policies. We see these processes and conditions as interconnected and mutually constituted following a political ecology approach which seeks uncover the political and power dimensions of environmental and ecological change (Robbins, 2019; Sundberg, 2011).

1.1 White settler colonialism, apex predators, and Indigenous people in the borderlands

In settler colonialism, "settler" populations arrive and establish themselves in new lands (Barnd, 2017). Simpson (2017) highlights "land" as central to settler colonialism: "colonizers want land" and therefore "everything else, whether it is legal or policy or economic or social," is part of settler colonialism "machinery" (p.15). Settler populations implement "a fundamental transformation in the demographics, cultures, and physical landscape of colonized lands," with the aim "to solidify territorial claims" (Barnd, 2017, p.9). This involves "the biopolitical and geopolitical management of people, land, flora and fauna," using certain "modes of control," including imprisonment, boundaries, and property regimes (Tuck and Yang, 2012, p.4-5). Borders, walls, and militarization are key components of white settler colonialism.

In the United States, attempts at wildlife eradication – particularly large carnivores and buffalo[2] – are rooted in historic and contemporary processes of white settler colonialism (Schneider, 2022). In the dispossession of Indigenous lands, particular species have been viewed as obstacles to "civilization" and settler land-uses, including homesteading, agriculture, and livestock rearing (Mamers, 2020). The mass killing of buffalo was a form of colonial control and spiritual genocide for tribal nations (Mamers, 2020; Schneider, 2022). Conservation and creation of "livable" settler conditions meant "extermination" and "control," both of animals and Indigenous peoples, a process which is ongoing though challenged by Indigenous resistance (Robinson, 2005; Simonian, 1995).

Wolves were a main target of white settler colonialism in the U.S. Predating the Declaration of Independence, the first government-to-citizen subsidies were bounties paid for wolf kills in New England (Robinson, 2005, p.32). In 1869, the Colorado legislature enacted wolf bounties, and other western states soon followed (Robinson, 2005, p.31). Western wolves were swiftly exterminated following these legislative changes and, in 1926, Yellowstone Park rangers killed the last American wolf, save for a small population that traversed the U.S.-Canada border (Ripple and Larsen, 2000). Shortly thereafter, in 1932, the US Senate Committee on Agriculture and Forestry supported additional funding for eliminating predators, saying: "the wolf and the coyote is not satisfied after he gets a living … they kill merely for the love of killing…" (U.S. Senate, 1932, p.25).

Despite near extermination of predators by the early-1900s, settlers continued claims that predator kills of livestock resulted in significant income losses. In 1930 Arizona, income losses by predatory animals were calculated to be $623,500 (U.S. Senate, 1932, p.162), despite that wolves, mountains lions, and coyotes had been largely eradicated (Robinson, 2005). Livestock losses to predators were very likely inflated by settlers (Robinson, 2005).

Recent anti-predator legislation demonstrates the extent to which settler discourses and attitudes are alive and well in wildlife management today (Oppie, 2021; Brasch, 2023). A 2021 law allows Idaho hunters to kill 90% of the state's wolf population, citing wolves' impacts on livestock and game species (e.g. deer, elk).[3]

2 In *Borderlands/La Frontera*, Anzaldúa (2012) presents the borderlands as a geographical and cognitive-social place that is constantly in transition. The U.S.-Mexico border is a "1,950 mile-long open wound dividing a pueblo" (p.24-25) where "two worlds merge…" creating "a shock culture, a border culture, and third country, a closed country" (p.33).

However, only 130 cattle and sheep – out of more than 2.7 million in the state – "were confirmed or probable(y)" killed by wolves in 2019-2020, and Idaho's elk population is at "an all-time high" (Oppie, 2021). Indeed, white settler colonial perceptions of wildlife have long been ingrained in American politics and environmental practice.

The U.S.-Mexico borderlands of Arizona are the ancestral homelands of numerous O'odham, Apache, and Yavapai nations. Starting in the early-1600s, the Spanish utilized violence, missions, and trade to control the region (Austin, 1991; Wright and Hopkins, 2016). After Mexican independence from Spain in the early 19th century, Indigenous peoples were considered Mexican citizens but were rarely informed of rights. Tribal nations like the Tohono O'odham continued to lose land to cattle ranches despite Mexican citizenship (Austin, 1991, p.99).

The Treaty of Guadalupe (1848) and Gadsden Purchase (1853) created the modern political border through transfer of substantial Mexican territories to the U.S (Austin, 1991; Molina, 2021). This led to increased settlement of land on the U.S. side of the border, and further dispossession from Indigenous nations (Wright and Hopkins, 2016; Human Rights Clinic et al., 2014). The U.S. government waited over a decade after the influx of Anglo settlers to reserve land for Indigenous communities, and reservations excluded core resources and settlements. For instance, in creation of the Gila River Indian Reservation and other O'odham reservations, tribal settlements, pastureland, mesquite grounds, and water sources were excluded (Wright and Hopkins, 2016). Water use by settler towns and farms led to catastrophic impacts for Indigenous communities, including recurring famines and poverty (Wright and Hopkins, 2016).

The modern political border between the U.S. and Mexico also split Indigenous nations' populations and territories (Austin, 1991). While tribal members in both U.S. and Mexican Tohono O'odham territories have sought to retain identity as a single tribe, it has been increasingly difficult with border militarization in the 20th century (Molina, 2021).[4] Tohono O'odham are also targeted, detained, and deported by Customs and Border Patrol (CBP), even when carrying identification on tribal land (Austin, 1991, p.101; Kowalski, 2017, p.646).

Other borderland tribes have also been impacted. A 1906 U.S.-Mexico treaty prohibits border wall in the Rio Grande River, so wall has been constructed a mile north of the border in Texas, significantly impacting wildlife and peoples, such as Lipan Apache, who can no longer access crucial river landscapes (Kowalski, 2017, 653; Human Rights Clinic et al, 2014).

Scholars have demonstrated how the eradication of wildlife and Indigenous people are co-constituted (Barnd, 2017; Global Federation of Animal Sanctuaries (GFAS), 2018; Mamers, 2020; Schneider, 2022). White settler colonialism has had major impacts for people and animals in the borderlands. These process, moreover, are not rooted in a colonial past, but ongoing, and constituted through current state-society interactions and political economic arrangements (de Leon, 2015; Tuck and Yang, 2012). The review of border and immigration policies below shows the extent to which ecology, race, and politics continue to be important factors that shape and transform the borderlands.

1.2 Jaguar histories in the borderlands

The jaguar has long played major roles in stories of many borderland tribes, including Yaqui, Hualapai, Yavapai, Tohono O'odham, Dine, and Zuni tribes (Molina, 2021; Pavlik, 2003). In February 2009, a male jaguar named Macho B was snared, sedated, and tagged with a radio collar by a jaguar researcher.[5] Twelve days later Macho B was euthanized due to injuries sustained in the capture. The Tohono O'odham tribe spoke against the animal's capture with an elder stating, "Whatever valuable data might be acquired, handling a jaguar in such a manner completely violates the traditional tribal view as to how we should deal with a fellow animal person" (Pavlik, 2003, p.171).

Yet, jaguars, seen as a threat to livestock, have long been a source of intrigue and obsession for white settlers. In 1930, the U.S. Secretary of Agriculture enacted a long-term "cooperative program for the eradication, suppression, or bringing under control of predatory and other wild animals injurious to agriculture" (U.S. Senate, 1932). The program included a provision that was already Arizona policy, "All Lobo wolves and jaguars will be taken as fast as they enter this State from Mexico and New Mexico, as 100 per cent of them live on livestock and game" (U.S. Senate, 1932, p.24).[6]

Roughly 80 jaguars were recorded in Arizona between 1858 and 2018, at least 57 of which were killed between 1858 and 1986 (Babb et al., 2022). However, this number is surprisingly low compared to other predators exterminated in the region. Jaguars' relative scarcity in 1800s historical records, particularly compared to wolves or mountain lions, indicates a lower population than expected given habitat conditions (Davis, 1982; Robinson et al., 2005). This is likely because jaguars were targets of colonial policies long before U.S. control of the Southwest (Robinson et al., 2005).

In 1617 – long before 18th century wolf bounties in New England – Spain's King Felipe II ordered the killing of predators in "New Spain," including modern day Arizona and New Mexico (Sundberg, 2011; Simonian, 1995). Large cats were particularly vilified by the Spanish, who introduced the practice of using dogs to chase large cats into trees, where they were shot (Simonian, 1995, p.36). By the time the U.S. gained control of the region in the 1840s, jaguar numbers reflected Spanish bounties and extermination practices (Robinson et al., 2005).

3 Before leaving office in 2020, Trump delisted wolves from federal protection under the Endangered Species Act and decentralized wolf management to individual states (Milman 2020).

4 From 1916 until the 1970s, Tohono O'odham children from northern Mexico attended Tohono O'odham schools in the U.S. (Molina, 2021, p.147, 129).

5 The event turned into a highly publicized investigation (see, for instance, Arizona Daily Star, 2017).

6 This act was deemed financially sound and extended in 1936 (Elliott, 1936).

In a government-commissioned 1859 survey of the U.S.-Mexico border, Baird (1859) speculated that while jaguars were still seen in Texas, they had been killed-off in other areas and had "a minor importance when compared with the puma[7]" in terms of threat to livestock (p.7). In northern Mexico he reported:

> vast number of pumas and jaguars [rely on] …. herds of wild cattle, mustang, mules, and horses … the Mexicans, who call it Leon, wage against it an unceasing warfare, on account of the ravages it commits among the cattle … the most effective means used for their destruction, in the bands of the Sonoranians, is strychnine. They poison with this substance the carcasses of the animals that have been slain, and not only often succeed in thus killing the Leones but a great number of wolves also…" (Baird, 1859, p.5-6).[8]

By the mid -1800s, according to Baird, jaguar extermination was common practice among ranchers in northern Mexico.

White settler colonial attitudes toward jaguars transcended the border, particularly among ranchers who viewed the animals as a major threat to livestock. Today, the most serious threat to jaguars globally is extermination by humans, largely pro-active and retaliatory killing from perceived and actual conflict with humans and livestock (Connolly and Nelson, 2023; Jędrzejewski et al., 2017; Knox et al., 2019).[9]

While there is recent evidence of Mexican ranchers poisoning jaguars (Arratibel, 2022; Kryt, 2019), it is important not to essentialize ranchers and other rural land-users as anti-predator and anti-jaguar. Several successful conservation collaborations exist wherein environmental organizations, ranchers, and others work to conserve habitat corridors and animals. In Sonora, Mexico, Northern Jaguar Project works with ranchers, rural community members, conservationists, and other stakeholders to conserve jaguar habitat and monitor animals, including through collaborative installation and monitoring of motion-triggered cameras on private land. Connolly and Nelson (2023, p.10) found that while some American ranchers feel jaguars "have not ever and should not now live in the United States," others value biodiversity and identify a need to collaborate with various stakeholders to maintain open space for both ranching and jaguars.

1.3 Modern jaguar geographies

Between 1996, when Border King was seen in southern Arizona, and 2023, at least seven male jaguars have been captured on camera traps in Arizona, presumably dispersing across the border from northern Mexico (Connolly and Nelson, 2023), where the nearest breeding population exists. Most recently, a previously unidentified jaguar was observed in late-December 2023 in southern Arizona (Center for Biological Diversity, 2024). Jaguars have large ranges and space requirements; home ranges for adult males can exceed 230 km^2 (Morato et al., 2016; Thornton et al, 2016).[10] Female jaguars disperse shorter distances than males (Sadowski-Smith, 2013; Povilitis, 2015). Landau et al. (2022) recently used presence-only and occupancy data to estimate that there is approximately 25,463 km^2 of suitable jaguar habitat in their study area, which included northern Mexico.

Sonora, the Mexican state that borders Arizona, contains an estimated 80-120 jaguars in the northern part of the state (Northern Jaguar Project, 2023). While several female jaguars and cubs have been spotted in northern Sonora, no female jaguar has been identified in the United States since the last female was shot in Arizona's White Mountains in 1963 (Brown and Lopez, 2000). Population health thus relies on the transnational movement of jaguars in core habitat and corridors (Culver, 2016).

19th century Mexican laws, along with habitat conditions, could explain why jaguar populations have been more stable in Mexico than the United States (Weber, 1982; Ceballos et al., 2021). In 1824, following Mexico's independence from Spain and due to increased U.S. settlers in the borderlands, the Mexican government made it illegal for non-Mexicans to hunt or trap "fur-bearing animals," including jaguars (Simonian, 1995, p.50). Furthermore, while the U.S. was experiencing a sense of "inexhaustible" resources in the 1880s, Mexico – conscious of water catchment and supply – implemented laws to preserve forests, which often coincide with jaguar habitat (Simonian, 1995, p.53). Mexico also has more land suited for jaguar habitat compared to the U.S (Ceballos et al., 2021). Policies to protect jaguars in Mexico have focused on local and regional conservation, along with surveying and monitoring. A recent survey found the Mexican jaguar population increased from 4,000 in 2010 to 4,800 in 2018 (Ceballos et al., 2021; also Rodriguez-Soto et al., 2013). In the borderlands, however, jaguar population health is also tied to U.S. policies and land-use practices.

As previously mentioned, settler colonialism, including the quest to control and militarize land, have long been detrimental to wildlife, particularly apex predators like jaguars. Ecological knowledge of trophic cascades has demonstrated how vital apex predators are to ecological systems. When large predators were removed from the western U.S. in the 1900s, increased prey species damaged plant communities, leading to erosion of riverbanks and floodplains (Beschta and Ripple, 2012; Ripple and Larsen, 2000). Jaguars, with large ranges and apex predator roles, also act as an umbrella species, and help maintain ecological processes such as controlling prey species and carcass provision for scavengers and other organisms (Connolly

7 "Puma" in this historic text refers to mountain lions.

8 Baird (1859) refers to "Leon" in "Mexican" as a panther (p.5).

9 Following centuries of jaguar eradication practices described above, jaguars are now listed as endangered under the Endangered Species Act in the U.S. (ECOS, 2024). Jaguars are on the International Union for Conservation of Nature (IUCN) red list (Quigley et al., 2017).

10 A study detected one male jaguar in the study area between 2012 and 2016, resident to southern Arizona's Santa Rita Mountains (Culver, 2016). The jaguar had a range of 90km^2 (Culver, 2016; also Eizirik et al., 2001; McCain and Childs, 2008). Sanderson et al. (2022), however, reviewed 25 years of research on jaguar habitat in larger geographical areas of Arizona and New Mexico and suggest a potential carrying capacity for the region of 90-151 jaguars.

and Nelson, 2023). Ecologists have recently called for "rewilding" practices vis-à-vis jaguar reintroduction that are "essential to species conservation, ecosystem restoration, and rewilding" (Sanderson et al., 2022, p.2). Conservation and rewilding efforts are particularly complicated in the U.S.-Mexico borderlands which have become increasingly militarized in recent years.

1.2 Border "security" and barriers in the neoliberal era

In the mid to late 20th century, the political division between the U.S. and Mexico "shifted from a border, a zone of gradual transition, to a boundary, a stark line of demarcation" (Nevins, 2010, p.147). Table 1 highlights important U.S. policies on border militarization and barrier construction. Funding for border militarization increased substantially during the 1990s "prevention through deterrence" (PTD) strategies, directed at barrier infrastructure, including fence and vehicle barriers, as well as video surveillance, vehicles, and personnel. A particularly pivotal year in border militarization was 1994, when historic urban crossing points were shut down and the U.S. government intentionally pushed people into harsh environments which resulted in migrant deaths (Andreas, 2000; Nevins, 2010; Sundberg, 2011; de Leon, 2015).

The practice of intentionally driving people into harsh and dangerous environments became known as the "funnel effect" (Rubio-Goldsmith et al., 2006; Soto, 2018). U.S. immigration officials used natural terrain – rivers, desert, mountains – as "deterrents to illegal entry" (U.S. GAO, 2017; U.S. Immigration and Naturalization Service (INS), 1996, p.24). Policy makers, moreover, anticipated Border Patrol agents would achieve a "tactical advantage" in apprehending people who attempted to cross through remote and difficult terrain (Sundberg, 2011, p.323; U.S. INS, 1996, p.3). In the 1990s, migrant deaths began to soar due to PTD interventions and policies (Cornelius, 2001; Michalowski, 2007). Between 1996 and 2000, migrant deaths in the borderlands increased 474%, including a 1,181% increase in deaths for people crossing into Arizona (Cornelius, 2001). de Leon (2015, p.4) argues the Border Patrol "disguises the impact of its current enforcement policy by mobilizing a combination of sterilized discourse, redirected blame, and 'natural' environmental processes that erase evidence of what happens in the most remote parts of southern Arizona." Border policy shifts in the 1990s gave rise to human smuggling networks and reflect ongoing practices of white settler colonialism wherein settlers' economic interests and control of land trump human life and rights (de Leon, 2015).

Operation Gatekeeper and other "prevention through deterrence" strategies also coincided with the North American Free Trade Agreement (NAFTA) of 1994 and the subsequent flooding of Mexican markets with U.S. corn and other agricultural products, which policy makers knew would hit rural farmers hard and increase undocumented migration (Ackerman, 2011; de Janvry et al., 1995). In other words, while 1990s neoliberal reforms created liberalized environments for the production and movement of commodities and capital, border militarization aimed to restrict the movement of people and labor.

The terrorist attacks of September 11th (hereafter 9/11) radically transformed border policies. Laws focusing on terrorism and security after 9/11 significantly extended the reach of the U.S. federal government along the southern border, and consolidated

TABLE 1 Key policies impacting border barrier construciton.

Key Policy	Year	Objective	Description	Examples of Important Implications
Southwest Border Enforcement Strategy	1994	"Prevention through deterrence".	Push migrants into dangerous physical geographies via "force-multipliers" (e.g., infrared scopes, video surveillance and fencing).	Tucson Sector: 75% increase in migrant deaths between 1990-2003 (U.S. GAO, 2001).
Illegal Immigrant Reform and Responsibility Act	1996	Prevent immigration.	Provided funding for U.S. Border Patrol.	Funding for early vehicle barriers built into this act.
Secure Fence Act	2006	Assume authority over borders through increased protection.	Post-9/11 act to control immigration. Rendered control of U.S.-Mexico Border to the DHS.	Facilitated waiving of long-standing federal regulations to build walls and vehicle barriers.
Obama Administration Fiscal Budget	2009	Cancel remainder of Secure Fence Act objectives.	Final 30 miles of barrier planned under Secure Fence Act not completed.	Barrier construction continued in 2008 and early-2009, mostly pedestrian fence and vehicle barrier.
Trump Administration Executive Order 13767	2017	Build wall along U.S.-Mexico border.	Diverted 3.8 billion dollars to border wall construction.	Mandated "immediate construction of a physical wall", defining "wall" as a "contiguous, and impassable physical barrier" (Executive Order 13767).
Biden Administration Executive Order 14010	2021	Halt funding of border wall construction.	Biden revoked or terminated eight executive actions relating to border security and immigration, including Trump's 2017 Executive Order 13767.	Construction of border wall halted. Barriers were not removed. In late-2023, Biden administration continued construction for wall funded/approved under previous administration (Executive Order 14010).

Source: Andreas (2000); Nevins (2010); Public Law (1996); Sundberg (2011); U.S. GAO (2001); GAO (2017); Painter and Singer (2020); US DHS (2021).

power under the U.S. Department of Homeland Security (DHS). In 2005, as part of the Real ID Act, DHS was allowed to "waive all laws as necessary to ensure expeditious construction of certain barriers and roads at the U.S. border" (H.R.418 – 109th Congress, 2005-2006, p.1). A year later, the Secure Fence Act (2006) authorized DHS's "operational control" of the border through numerous tactics, including building roads (Painter and Singer, 2020, p.3). The waivers allowed for immediate road building, use of off-road vehicles, and setting up camps in wildlife refuges and other state and federal lands (Sundberg, 2011). DHS rapidly utilized these new powers, and in less than a year, waived many long-standing federal regulations (e.g. Endangered Species Act) to build border fence (Nuñez-Neto and Garcia, 2007).

Border barrier expansion continued after 9/11, during both democratic and republican administrations. Under the Obama administration, over 209 km of border barrier was built, almost all during his first year in office (Montoya Bryan, 2019). Funding for this construction was largely approved in the previous administration, and border barrier construction was essentially halted in 2010 (Painter and Singer, 2020).

From 2016-2020 President Trump redefined border security along the U.S.- Mexico border (Painter and Singer, 2020). The DHS under Trump used the Illegal Immigration Reform and Immigrant Responsibility Act of 1996 (IIRIRA) and Real ID Act to waive regulations.[11] As previously mentioned, these actions followed a campaign that vilified Mexican migrants and promised to "build the wall" to curb migration (Finley and Esposito, 2020; Horton, 2021). Trump's rhetoric framed refugees and immigrants as cop murderers and included an ad so extreme that even Fox News refused to air it (Grynbaum and Chokshi, 2018). The Trump administration oversaw reinforcement of 700 km of existing border fence with taller, thicker barriers, and built an additional 120 km of fence (Giles, 2021). For our study area, we mapped these shifts in border barriers between 2005 and 2021, and examined the relationship between border barrier and suitable jaguar habitat.

1.5 Wildlife and militarized lands

Borders and militarized zones can have contradictory implications for wildlife. While border barriers can limit animal movement, they can also limit human movement and development, thereby providing wildlife protection from humans (Trouwborst et al., 2016). Borderlands also serve as refuge for animals hunted and exterminated in interiors of countries, for instance wolves along the U.S.-Canadian border and cranes in the Korean Demilitarized Zone (Ripple and Larsen, 2000; Kim, 2013). In Kashmir, by contrast, fencing and conflict have pushed leopards into urban areas and in direct conflict with humans (Habib et al., 2015).

Trouwborst et al. (2016) note that the type of barrier or militarized zone hugely impacts wildlife. Fences and walls, for instance, are designed to be impenetrable and thus directly curtail animals' mobility, fragment populations and cause direct mortality (Trouwborst et al., 2016). Fences and walls limit movement and thereby reduce access to water, food, and mates for wide-ranging and migratory species, including those with fragmented habitats (Liu et al., 2020). Large carnivores and herbivores are particularly vulnerable to the deleterious impacts of fences and walls (Linnell et al., 2016).

In the U.S.-Mexico borderlands, wall construction has directly reduced the area, quality, and connectivity of available habitat by physically limiting wildlife movement, and dispersal of species that cannot climb or move through existing walls (Chambers et al., 2022; Flesch et al., 2010; Peters et al., 2018). Wall and fence infrastructure are expected to divert dispersing jaguars and have already been shown to divert movement of other species in the region (e.g. mountain lion and coati) (Chambers et al., 2022; McCallum et al., 2014).

Furthermore, Kamath and Wesner (2020) historicize and contextualize the concept of territoriality in biology, reminding us that animals do not always behave how humans predict. The authors urge scholars to demonstrate the function of animal behaviors and specific relationships among individuals rather than assuming particular responses or dynamics are at play. This is particularly important with respect to our habitat model, and our results on what percentage of potential habitat has been cut off by border barrier.

2 Methods

2.1 Study area

We mapped jaguar observations for two temporal periods in the American southwest (Figure 1).[12] Figure 1 maps jaguar observations between 1840-1910, based on historical documents. This is also a time that corresponds with the predator eradication practices described above. Figure 1 also maps jaguar sightings between 1996 and December 2023. While suitable jaguar habitat may include historic ranges into northern areas of the American southwest (e.g. southern Colorado), as indicated in Figure 1, jaguar observations since 1996 remain within 100 km of the U.S.-Mexico border (Figure 1).

11 In 2020, the DHS announced six environmental waivers for wall construction projects along the border, citing Sec. 102 of IIRIRA (U.S.CBP, 2020). In early 2021, DHS again cited IIRIRA, along with the REAL ID Act, to waive regulations and speed-up wall construction processes before Trump left office (U.S. DHS, 2021, 2021b).

12 To create Figure 1 we mapped geographic locations of known jaguar observations using data found in the U.S. Fish and Wildlife's online jaguar database (USFWS, 2024). It is important to note that historic coordinates may lack geographic accuracy and represent generalized locations (e.g. mountain range). Historic observations were often represented as polygons in the database, indicating general locations of jaguar observations. Polygons were imported into ArcGIS Pro and a center point within each polygon was estimated for mapping purposes. However, the actual observation may have been within a 50 km radius from that center point. Jaguar observations in the database since 1996 are based on ecological studies and provide specific geographic coordinates. These coordinates were migrated to ArcGIS Pro as points.

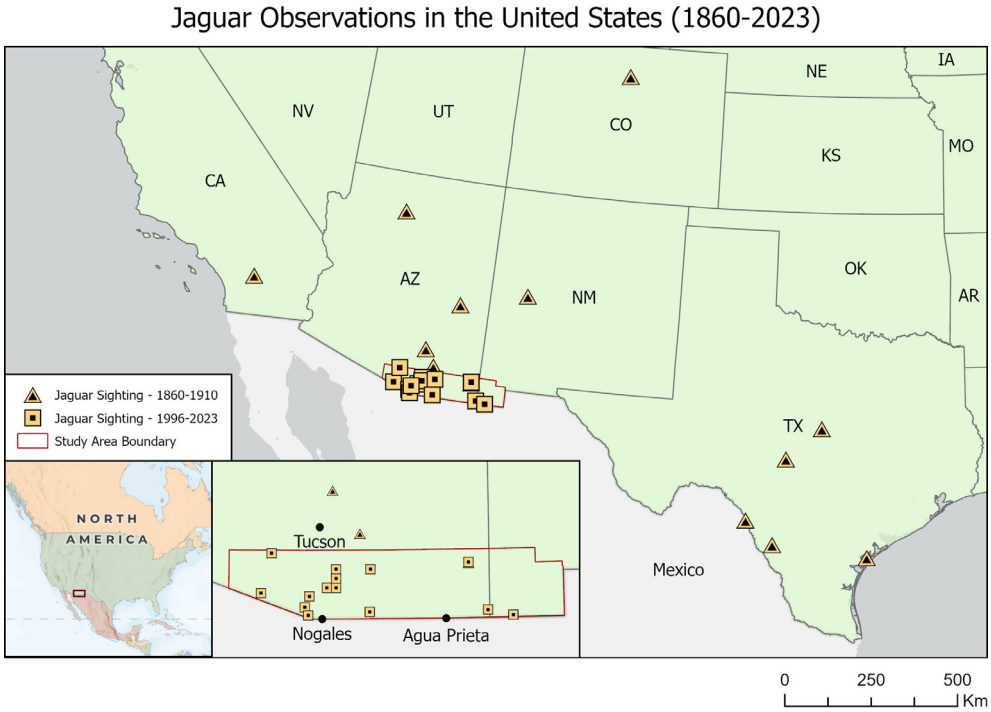

FIGURE 1
Jaguar observations in U.S. between 1860 and 2023. Data on jaguar observations were obtained from U.S. Fish and Wildlife Service and Wildlife Conservation Society (2024).

Our study area thus extends from Baboquivari Peak Wilderness in Arizona to the southeast corner of Hidalgo County, New Mexico. This area was selected based on recent documentation of jaguars in the area (Culver, 2016; Hatten et al., 2005) (Figure 1). The North-South dimensions of the project were less important, as this research specifically was meant to measure habitat on the border.[13] The selected study area also largely corresponds with other studies that have examined contemporary jaguar habitat in the U.S. (e.g. Chambers et al., 2022; Culver, 2016; USFWS, 2014).

Our study area contains a variety of elevations and vegetation zones, largely due to the Madrean Sky Islands, which are 55 mountains covered with pine and oak trees, at the highest elevations, and separated by desert and/or grassland topographies (Connolly and Nelson, 2023). A sky island often covers six different biomes, from the low elevation scrubland, to oak, and then high elevation fir forests (Connolly and Nelson, 2023). The average annual rainfall for our study area is about 400 mm, the majority occurring from July through September.[14] The sky islands exist across southern Arizona, southwestern New Mexico, and the Sonora and Chihuahuan Deserts in Mexico, and are important habitat and corridors for jaguars and other endangered species (Chambers et al., 2022).

A 2014 U.S. Fish and Wildlife Service (USFWS) report identified important factors for suitable jaguar habitat, including availability of prey, access to water, cover and terrain, and density of nearby human populations (USFWS, 2014; Chambers et al., 2022). Higher levels of canopy cover, along with desert springs and narrow canyons are ideal habitat for jaguars, and jaguars detected in grasslands were usually in rocky canyons (Chambers et al., 2022; Culver, 2016).

2.2 Geospatial analysis

While this study largely draws from the geospatial methods described below, we also found and reviewed legal and historic documents from various entities including the U.S. military, Department of Defense, and environmental organizations.

Our first objective was to model suitable jaguar habitat. We drew from ecological studies to identify important jaguar habitat variables (Culver, 2016; Hatten et al, 2005; Sanderson et al., 2022) (Table 2). Historic and recent jaguar observations in our study area demonstrate jaguars remain 1-10 kilometers (about 6.21 mi) from water sites and generally prefer forested and grassland communities. As solitary animals, jaguars generally avoid human development and major roads by 8-9 kilometers. While jaguars have been recorded at multiple elevations, they

13 This project required all sources to be projected into the same geographic coordinate system, NAD83 / UTM Zone 13N. Some data sources were originally projected in WGS, requiring geographic transformation which may have offset the data by 0.1-meter accuracy (Esri, 2023a).

14 The study area of southern Arizona and southwestern New Mexico contains elevations between 500 m and 2,900 m, with high temperatures at lower elevations reaching 40C, and higher elevations reaching 30C (Culver, 2016).

generally prefer regions between 1,200-1,800 meters in elevation (Culver, 2016; Hatten et al., 2005). Using presence-only and occupancy data, Landau et al. (2022) suggested high terrain ruggedness and presence of riparian vegetation were most strongly related to habitat use by jaguars.

For each variable identified in ecological studies as important for determining jaguar habitat, we obtained publicly available data (Table 3) and performed a spatial analysis using ArcGIS Pro version 2.8.0. All non-raster data were converted to raster format and set to a 30-meter pixel resolution.[15] An overlay analysis was then performed using ArcGIS Pro to designate areas as habitable or uninhabitable (Esri, 2023b). The formula H = v1 * v2 * v3 * v4 * v5 * v6 was applied to each cell. In this formula, every habitat variable (v) from Table 2 was assigned a value of 1 or 0 depending on whether it met the standard of jaguar habitability (1) or not (0). Jaguar habitability for each cell was determined by the outcome of H, so that only cells meeting all requirements of variables could be considered suitable habitat.

Our second objective was to map expansion of border barriers between 2005 and 2021. Table 3 highlights data used to map barriers.[16] To analyze barrier expansion, three years were selected: 2005, 2015, and 2021. These years were selected as they capture status of the border before and after the 2006 Secure Fence Act, and border barrier expansion under the Trump administration between 2017 and 2021. Preliminary review of existing literature and policy documents indicated these years and policy shifts were pivotal for border barrier changes (Table 1).

Border barriers were visualized using polyline shapefiles for the three years.[17] Information on areas covered by polylines and attributes was derived from pre-existing spatial data (U.S. Immigration and Customs Enforcement, 2013; Wildlands Network, 2021) that required georeferencing (Table 3). These data sources were compared to polylines digitized using aerial imagery. Comparing maps and polyline vector data to digitized polylines allowed for better accuracy when georeferencing and provided insight on gaps in border barrier.

Border barrier was visualized in two different ways: temporal change and wall type. Visualization for both was fulfilled by differentiating attribute fields for the polylines. Polylines for all years were split into separate segments that deciphered temporal change for the following categories:[18] 1) new footprint (new footprint of border barriers; no barrier existed during previous time period); 2) replacement (prior time period showed barrier existed but was replaced); 3) no change (barrier did not experience change between the two periods).

The second visualization was intended to display the different types of barriers identified during each year. Data provided from Wildlands Network provided descriptions of barrier type by location (Wildlands Network, 2021). Elaborations on definitions of barrier were provided by the Department of Homeland Security (U.S. DHS, 2021a, U.S. Department of Homeland Security, 2016b). From these definitions, we created attribute fields in border barrier polyline data that separated "vehicle barriers" from "walls."

3 Results and Discussion

3.1 Extent of jaguar habitat

Our analysis revealed suitable jaguar habitat in our study area in 2021 was 11,385 km^2 (Figure 2). The amount of jaguar habitat adjacent to the border in our study area is 155 kilometers, though it

TABLE 2 Ideal variables for jaguar habitat (Culver, 2016; Hatten et al., 2005; Sanderson et al, 2022).

Variable	Description	Dataset Used
Elevation	Suitable habitat exists between 1000–1800-meters above sea level (asl).	U.S. Geological Survey Digital Elevation Model (raster)
Land Cover	Does not include barren land, cultivation, or human development.	National Land Cover Database (raster)
Human Development	No human development within 1000 meters of habitable areas.	National Land Cover Database (raster)
Water Sources	Habitable areas exist within 5000 meters of major rivers.	National Atlas Linear Water Sources (vector)
Major Roads	Habitable areas must not exist within 1000 meters of major roads.	U.S. Census Bureau Roads (vector)
Minor Roads	Habitable areas must not be covered by bike trail, pedestrian walkway, or dirt trail.	U.S. Census Bureau Roads (vector)

15 Each dataset was delineated into a separate variable based on key habitat conditions for jaguars (Table 2). Distance-based vector values (water sources, major roads) were defined using the ArcGIS Pro Euclidean distance tool, which calculates the distance from the source (vector-based roads and water features were converted to raster) to the center of all surrounding cells (Esri, 2024).

16 All aerial photography data were georectified.

17 Separate shapefiles of border barriers displayed as polylines were created for 2005, 2015, 2021 to compare years with different attributes and to display temporal data.

18 Since each selected year in this task required comparison to the period before it, the 2005 dataset did not need these attributes added to it. Attributes were created in the polyline layers for 2015 and 2021.

10.3389/fcosc.2024.1355997

TABLE 3 Geospatial, environmental, and quantitative data used.

Data Source	Type of Data	Definition	Utilization
United States Census Bureau (USCB, 2020; UCSB, 2022)	**Name:** U.S. Census Bureau Roads **Format:** Vector geospatial data. **Description:** TIGER Geodatabase / vector roads **Data Collection Period:** 2022 **Release:** 5/1/2022	Major roads are all U.S. Census defined primary and secondary roads, including interstates and state and county highways. Local neighborhood roads, city streets, or trails are "minor roads."	Model jaguar habitat - proximity to roads.
National Atlas of the United States, United States Geological Survey (USGS, 2012)	**Name:** National Atlas Linear Water Sources **Format:** Vector geospatial data. **Description:** Linear water sources **Data Collection Period:** 1995-2012 **Released:** 7/1/2012	Linear water sources, including perennial or intermittent bodies of flowing water.	Model jaguar habitat - proximity to perennial and intermittent water sources.
United States Geological Survey (USGS, 2021)	**Name:** National Land Cover Database **Format:** Raster geospatial dataset / **Description:** Land Cover **Data Collection Period:** 2001-2019 **Released:** 6/4/2021 **Resolution:** 30 meters.	Land cover data provides rigorous categorization of Landsat satellite imagery under a 16-class legend based on a modified Anderson Level II classification system.	Model jaguar habitat – proximity to developed spaces; designate habitable land.
United States Geological Survey (USGS, 2021b)	**Name:** U.S. Geological Survey Digital Elevation Model **Format:** Raster geospatial dataset **Description:** Digital Elevation Model (DEM) **Data Collection Period:** 2021 **Released:** 12/29/2021 **Resolution:** 30 meters	A digital elevation model (DEM) provides information on elevation in a region. All elevation units are collected in meters.	Model jaguar habitat – designate suitable elevation.
Wildlands Network (2021)	**Name:** Wildlands Network Data **Format:** Vector geospatial set **Description:** Ground-truthing of types of barriers at U.S.-Mexico border. **Data Collection Period:** January 2021 – July 2021 **Released:** 7/11/2021	Provides ground-truthing assessment of border wall status as of 2021. Categorizes border wall built between 2017-2021, border wall built between 2008-2016 that were still standing in 2021, and borders built before 2008 that were still standing in 2021.	Differentiation of different types of barriers and years built at the border.
Immigration and Customs Enforcement (US ICE, 2013)	**Name:** ICE Border Wall Location Map Series **Format:** Digital hardcopy map series **Description:** Border barrier locations and types. **Data Collection Period:** 2013 **Released:** 10/23/2013 **Scale:** 1:50,000 measured on 11x17" print. Digitized at 1:50,000 scale.	Temporal Instant Extent: 2013 Released: October 23, 2013 Hardcopy map series of final border wall locations, obtained and released for public use by University of Texas School of Law under the Freedom of Information Act.	Differentiation of border barrier type assistance, assistance in digitizing border barrier.
United States Department of Agriculture (NAIP 2022)	**Name:** NAIP Aerial Imagery **Format:** Raster geospatial dataset **Description:** National Agriculture Imagery Program (NAIP) aerial imagery **Data Collection Period:** 2013, 2021 **Released:** 10/30/2022 **Resolution:** 1 meter	Temporal Instant Extent: 2013; 2021 Publicly available digital ortho-photography provided by NAIP. High resolution photography allows for accurate digitization and georeferencing.	Assistance in digitizing border barrier.
Airbus/ Maxar Technologies	**Name:** Google Earth Imagery **Format:** Google Earth 3D representations of orthoimagery. **Description:** Digitized in Google Earth Engine. **Data Collection Period:** 2005-2021 **Resolution:** Unknown	Google Earth Imagery digitized in Google Earth and converted to shapefile format for usage in ArcGIS Pro. Digitized approximately 5-10 meters above ground level.	Assistance in digitizing border barrier.

is important to note that this is not a contiguous distance. Figure 2 thus identifies areas that would likely serve as points of core habitat and connectivity with Mexico.

We also understand that jaguar and other wildlife movement and behaviors may not overlap perfectly with these areas (also Landy et al., 2018; Grigione and Mrykalo, 2004). For instance, while we mapped jaguar habitat to not exist within 1000 meters of human development based on Culver (2016) conditions for jaguars, research has shown border barriers and militarization have pushed large carnivores into cities and areas of human development (Pahalwan, 2007; Habib et al., 2015). Suitable habitat conditions must thus be taken with a grain of salt, and researchers should be open to surprises and unpredictability in animal behavior, perhaps especially in areas where habitat and corridors have been cut off quickly by human-constructed barriers (Kamath and Wesner, 2020; Wilkinson et al., 2021). Border barriers, and impenetrable wall in particular, may profoundly reshape jaguar geographies and human-wildlife interactions.

FIGURE 2
Suitable jaguar habitat cut off by border barrier in 2021. Tables 1 , 2 detail datasets and variables used to map suitable jaguar habitat.

3.2 Expansion of border barrier and type

We analyzed the expansion of border barrier between 2005-2015 and 2016-2021. Our results are visualized in Figures 2–4 and discussed below.

3.2.1 2005-2015

The largest expansion of new barrier footprint is between 2005 and 2015 (Figure 3). This is unsurprising given that previously discussed post-9/11 policies allowed for carte-blanche dismissal of federal environmental protections in the name of border "security" and militarization. Times of crisis, including 9/11, can lead to reconsolidation of settler claims on territory and reinforcement of a dominant discourse of the "exceptionalism" of the settler state (Bruyneel, 2014).

Nearly 200km of new barrier was constructed between 2005 and 2015, bringing the total barrier distance to 253km. In other words, by 2015, for our study area, which has a total length of 366.58 km at the U.S.-Mexico border, 82.7% was covered by some type of barrier. During the same period, less than 1km of border barrier was replaced, further demonstrating the emphasis on new construction during this time period.

Yet, the type of barrier constructed during this period is important: 42% was wall, and 58% was vehicle barrier (Figures 3, 4). Vehicle barrier is typically made of steel and intended to prevent vehicles from crossing the border.[19] While there are different types and heights of vehicle barrier, much of the vehicle barrier installed at the border during this time was approximately 4-6 feet high (Greenwald et al., 2017) and has large openings (5 feet) between the bars (National Park Service, 2003).

Some animals can easily cross vehicle barriers (Greenwald et al., 2017; Prieto, 2020) (Figures 5, 6).[20] Jaguars, for instance, have a vertical jump capacity of approximately 10 ft, allowing them to clear a 4-6 ft vehicle barrier (GFAS, 2018; Greenwald et al., 2017). Deer, pronghorn and mountain lions may also be able to jump short border fences and vehicle barriers (Figure 4), while smaller animals can slide through gaps between bars (Figure 5). In other words, while there was great expansion of border barrier between 2005 and 2015, the majority of this barrier may have been obstacles animals could cross. By contrast, replacement of vehicle barrier with wall under Trump likely possesses greater impacts for wildlife.

3.2.2 2016-2021

In 2017, Executive Order 13767, issued by newly elected President Trump, diverted 3.8 billion dollars to border wall construction (Executive Order 13767). Trump's executive order called for "immediate construction of a physical wall," defining 'wall' as a "contiguous, impassable physical barrier" (Executive Order 13767). Yet, while Trump touted the wall as impenetrable, saying "it's as strong as you're going to get and strong as you can have" (White House, 2021), some sources have pointed to poor construction, including a section of wall in California that fell over from 30 mph wind (BBC News, 2020).

19 Vehicle barriers include legacy vehicle fencing and VF300 constructed fence, while "walls" include legacy pedestrian fencing, pedestrian fencing, PF225 constructed fence, PF70 fence (Department of Homeland Security, 2016).

20 These photographs are reproduced with permission of the photographer, Alejandro Prieto.

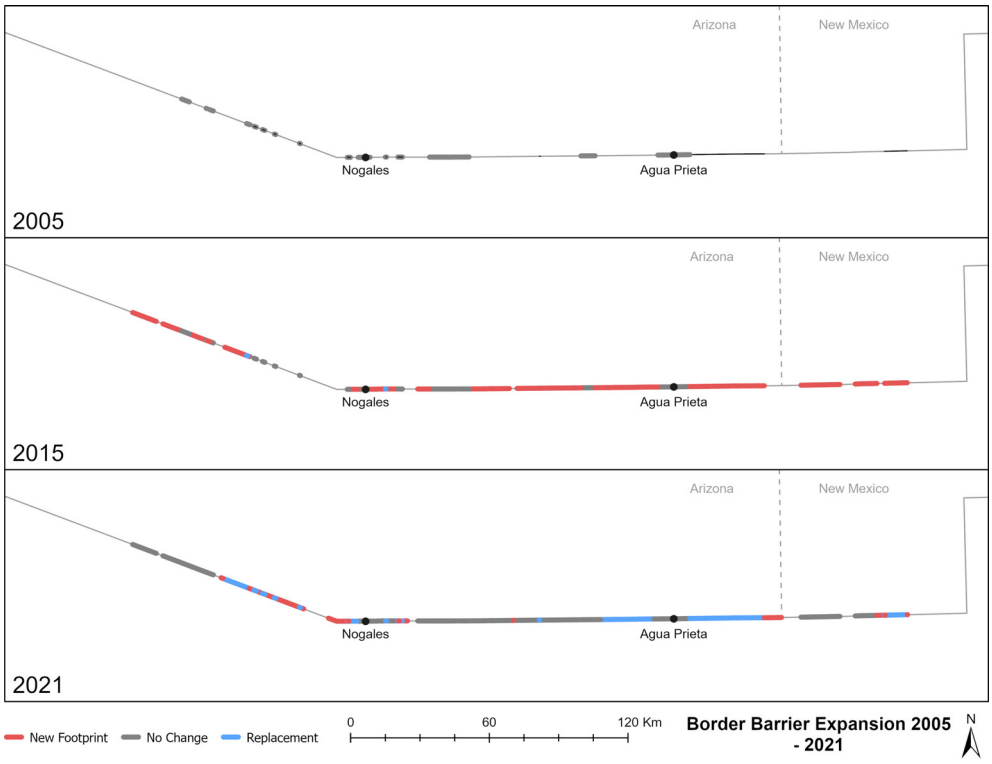

FIGURE 3
Border barrier expansion 2005-2021. Table 2 details datasets used to map border barrier.

In our analysis, 49.5 km of new border wall was constructed in our study area under Trump between 2016 and 2021.[21] Additionally, the Trump administration replaced 47 km of existing vehicle barrier with wall meant to be impenetrable to both people and wildlife. Figures 3, 4 illustrate these changes.

The border wall constructed under Trump is typically 30 feet high and made from steel bollard (Wildlands Network, 2021). In other words, within our study area, 96.5 km of border became uncrossable during this time, which potentially devastating impacts for wildlife including jaguars (Greenwald et al., 2017; Peters et al., 2018). A 2017 report on the potential impacts of Trump wall building activity, stated that "the wall and concurrent border-enforcement activities" are predicted to be both a human-rights disaster and severely "impact wildlife and the environment," with a likely outcome of "the extinction of the jaguar, ocelot, cactus ferruginous pygmy owl and other species in the United States" (Greenwald et al., 2017, p.1).

Under Trump, U.S. Customs and Border Protection (CBP) also blasted through Guadalupe Canyon in the Peloncillo Mountains, where Border King was observed in 1996, a highly valuable wildlife route between the U.S. and Mexico (Kapoor and Brocious, 2020; Miroff, 2022). Wall construction in Guadalupe Canyon was extremely expensive due to destruction of the Peloncillo Mountains and poor preparation (Painter and Singer, 2020, p.16), costing over $41 million per mile (Kapoor and Brocious, 2020; Miroff, 2022).

Indeed, border wall construction under Trump focused on federal lands, and not on areas CBP identified as priority zones, which were more often private lands. Wall construction on private land often stalled, deterred by lawsuits from landowners (Clapton, 2022; Nixon, 2017). There is speculation that due to complicated legal implications of accessing and walling private land, the Trump administration focused on remote federal lands and land held in federal trust (i.e. Bureau of Land Management, wildlife refuges, and tribal lands) because of the relative ease of waiving federal and state legislations to construct wall on these lands, despite these areas not being top priority migrant crossing points determined by CBP (Nixon, 2017; Miroff, 2022). Motion-activated cameras at gaps in a Trump-era wall captured only wildlife over several months, and no people (Miroff, 2022).

3.3 Habitat impacts of border barrier

Within the study area, the spatial footprint of all border barrier was 303 km by 2021. In other words, 82.7% of the border (for our entire study area) had barrier by 2021 (Figures 2–4).[22] Figure 3 visualizes the growth and changing type of border barrier between

21 Trump took office in early-2017 and our analysis revealed that most of this expansion and construction happened after Trump was in office.

22 P=((H-B)/H) x 100. This percentage (P) was calculated by subtracting the total suitable jaguar habitat that touches the U.S.-Mexico border (H) in our study area by the length of border barrier that overlaps with suitable jaguar habitat (B) and calculating the final percentage of unbarricaded habitat in total suitable habitat.

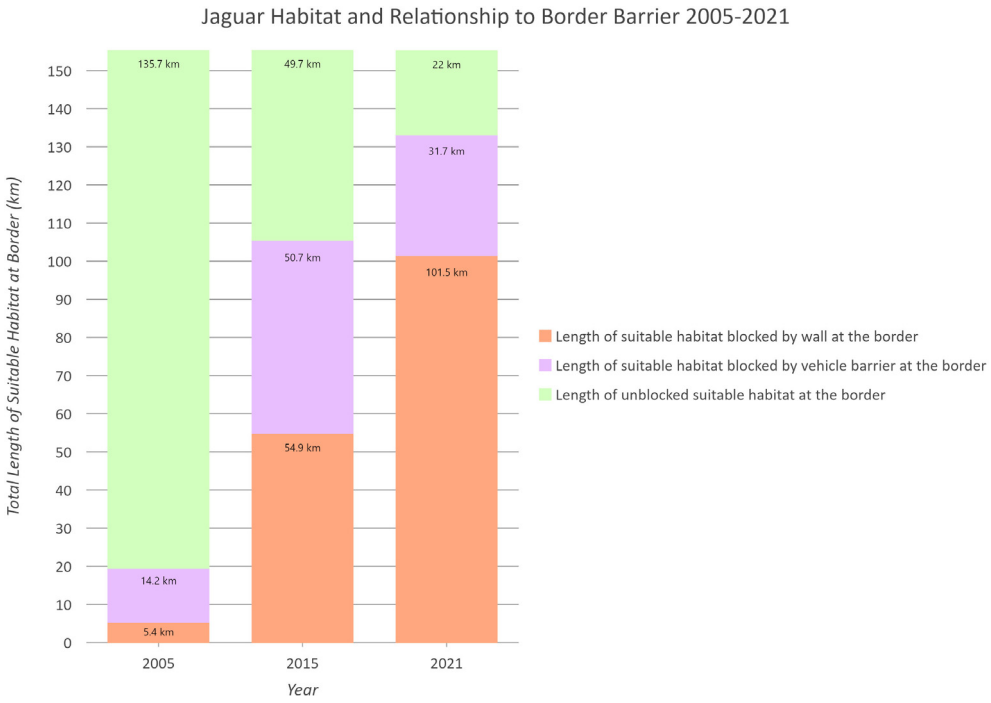

FIGURE 4
Relationship between suitable jaguar habitat and type of barrier in study area 2005 to 2021. Tables 1, 2 detail datasets and variables used.

2005 and 2021. Of this 303 km in 2021, 67% was wall and 33% was vehicle barrier (Figures 3, 4). Of the suitable jaguar habitat that touched the border in the study area (155 km), 86% (or 133 km) had been cut off by border barrier by 2021 (Figure 2). Of this barricaded distance, 76.74% was wall and only 23.26% remained vehicle barrier which, again, jaguars and other wildlife are more likely to cross (Figures 3, 5, 6).

The border wall has significantly degraded landscape connectivity. The physical barrier disrupts migration and dispersal routes, preventing wildlife from accessing critical resources including food, water, and mates (Peters et al., 2018). It is increasingly difficult for large endangered animals such as the jaguar, Mexican gray wolf, and Sonoran pronghorn to disperse across the border, fragmenting already at-risk populations (Connolly and Nelson, 2023; Peters et al., 2018). Nearly 100 km of pedestrian fence south of Tombstone, Arizona, for instance, bisects an otherwise probable movement corridor for jaguars, preventing dispersal through this region (Landau, 2020, p.40).

FIGURE 5
Mountain lion jumps over vehicle barrier on U.S.-Mexico border (photo credit: Alejandro Prieto).

FIGURE 6
Javelina crosses U.S.-Mexico border through opening in vehicle barrier (photo credit: Alejandro Prieto).

Chambers et al. (2022) predicted border wall construction would result in an increase in the amount of energy jaguars would expend while looking for routes around the wall. Changing access to prey and increased energy expenditures may further threaten jaguars' "reproductive success and survival" (Chambers et al., 2022, p.7). Since all known breeding populations of jaguars are south of the border (Culver, 2016), walling habitat corridors has signficant implications for jaguar survival in the U.S.

Jaguars, moreover, are not only impacted by physical barriers, but by the overall militarization of the region. Jaguars prefer secluded areas and are deterred just by the presence of roads, checkpoints, and lights (Bleir, 2020). Border construction has also dammed up streams and drainages, removing critical water resources that jaguars and other animals rely upon in a desert environment (Wildlands Network, 2021).

4 Conclusions and broader implications

Border wall expansion – justified through xenophobic discourses while masking the uneven impacts of neoliberalism – is part of long history of white settler colonialism in the borderlands that endangers human, wildlife, and plant lives. Neoliberal policies (e.g. NAFTA) and crises (e.g. 9/11) justified disregard for habitat, environmental laws, species protection, and human rights to privilege border "security."

Despite these measures, undocumented immigration has not declined (TRAC Immigration, 2023). To the contrary, border militarization and enforcement has given rise to a large criminal network of human smugglers to whom migrants pay large sums to lead them across the border (Slack and Martínez, 2018; de Leon, 2015; Michalowski, 2007). Due to the dangers and high costs associated with border crossing, moreover, undocumented migrants stay for longer periods of time in the U.S. than ever before, separated from families and taking on great risk in low paid industries (Michalowski, 2007; Jusionyte, 2018). Despite increased border militarization and its many social and ecological implications, undocumented migration continues (TRAC Immigration, 2023).

The wall thus continues to be a tool of settler-colonialism to control land and perform settler colonial political rhetoric. In the borderlands, this tool has had significant implications for people, including migrants, Indigenous peoples, and wildlife. Our results show that by 2021, of the potential jaguar habitat that touched the border in our study area (155 km), 86% was cut off by border barrier. Of this barricaded area, moreover, more than three-quarters was wall, which is impenetrable to most terrestrial, non-volant animals.

In 2021, the Biden administration issued Executive Order 14010 halting the funding of new border barrier construction. Biden revoked or terminated eight executive actions relating to border security and immigration, including Trump's 2017 Executive Order 13767 (Border Security and Immigration Enforcement Improvements). Although the Biden administration claimed it was committed to halting wall construction, unfinished and/or unstable wall has been repaired under Biden[23] (U.S. Department of Homeland Security, 2016b; Miroff, 2022).

In October 2023, the Biden administration said it would continue building 20 miles of border barrier, waiving environmental regulations to complete construction. The administration stated construction continues because funding was already approved by Congress in 2019 (Sullivan and Edmonds, 2023). Biden also rejected calls to remove existing border barriers and allowed CBP to close gaps in the wall, which wildlife biologists say are crucial for wildlife movement (Miroff, 2022).

Indeed, much precarity and ambiguity exists about the future of jaguars in the borderlands. What is clear is that jaguar conservation must include the maintenance of existing, if severely diminished, transnational habitat corridors in the U.S.-Mexico borderlands.

23 Some sections of border wall were left unstable after contractors rushed to complete construction at the end of the Trump's term (Miroff, 2022).

Various stakeholders and epistemologies also need to be included in conservation efforts, including the privileging of Indigenous perspectives on jaguar management (Svancara et al., 2015; Cassaigne et al., 2016). Indigenous people have, after all, managed desert wildlife and landscapes long before settlers occupied the region and created the border.

Finally, human-wildlife interactions are often context specific, shaped by place-based environmental histories, physical geography processes, and ecological dynamics. Thus, there is no one-size-fits-all solution to wildlife management and conservation, and conservationists must understand the extent to which current barriers and challenges are situated in long histories of settler colonialism.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material. Further inquiries can be directed to the corresponding author.

Author contributions

HH: Conceptualization, Investigation, Project administration, Resources, Supervision, Writing – original draft, Writing – review & editing. EH: Data curation, Formal analysis, Methodology, Visualization, Writing – review & editing. ZW-H: Investigation, Writing – original draft, Writing – review & editing.

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