Border Walls and Biodiversity

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New barriers, new horizons

At the US–Mexico border at the Coronado National Memorial/Roosevelt Easement. The wall and wide patrol road cause habitat fragmentation, threatening the well-being of many species. Photograph: Matt Clark/Defenders of Wildlife.

Can a wall impede a bird capable of flying? It seems illogical. But the ferruginous pygmy owl is not a high flier. In the Sonoran Desert in southern Arizona, these owls do not even readily fly over trees. "They fly really low," with an average flight height of 1.4 meters (m) above ground, explains the University of Arizona's Aaron Flesch. Flesch's telemetry work suggests that habitat use by these low-flying birds is profoundly curtailed by fragmentation and barriers.

When he first started his borderlands research near the boundary between the United States and Mexico, "I was thinking about roadways," Flesch says. He soon learned that not only large roadways but also big agricultural fields and other

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A javelina (peccary) (left) and cottontail (right) along the US–Mexico border confront an obstacle too big to overcome. Photographs: Matt Clark/Defenders of Wildlife.

types of landscape disturbance and segregation "affected the movement of these critters," he says. His journey of borderlands discovery began nearly 20 years ago. Back then, Flesch never anticipated plans for a complete border wall.

Walls and barriers along international borders are not new. Famous historical examples include Hadrian's Wall of the Roman Empire, the Great Wall of China, and the divisive Berlin Wall that fell in 1989. The extent of border structure construction briefly flagged following that historic event, which rejoined East and West Germany. But global wall building has undergone a resurgence since the terrorist attacks of September 11, 2001. A recent estimate puts the total length of border fences in Eurasia alone, excluding the Middle East, at approximately 30,000 kilometers (km).

Now, though, as plans emerge for a complete wall between two countries that rank among the 17 most "megadiverse" nations in the world—the United States and Mexico—it is ever more timely and important to understand the impacts of international border structures on biodiversity.

A special kind of barrier

What are the potential impacts of a barrier along the full 3200-km (or 2000-mile) border between the United States and Mexico? It is an open question. However, many of its possible impacts can be predicted on the basis of habitat connectivity and social-science research at this and other international borders.

Barriers to animal movement have long held the interest of biologists. Natural biogeographical barriers sparked the curiosity of de Buffon and Linnaeus in the 1700s, leading to their novel ideas about *dispersal*, the process that ecologists define as animal movement that can lead to gene flow. Then, in the 1800s, Darwin and Wallace marveled over the evolution of new species isolated on islands. In the 1960s, Frank Preston formalized the idea of the species–area relationship, and Robert MacArthur and Edward O. Wilson developed island biogeography theory to explain how species richness on islands of different sizes could be predicted from patterns of colonization and extinction.

More recently, biologists have focused investigations on the biological impacts of anthropogenic barriers such as habitat fragmentation, dams, and roads. Oddly, although the biodiversity impact of habitat fragmentation has been an active research area for decades, the biodiversity impacts of border structures have not. John Linnell, senior researcher at the Norwegian Institute for Nature Research in Trondheim, writes in his coauthored 2016 analysis of border-security fencing in *PLOS Biology*, "It is somewhat ironic that for the last 15 years, while conservation biologists have been largely promoting transboundary management and celebrating localized examples of fence removal, the global trend has been for an unprecedented increase in barriers preventing wildlife from moving across borders."

But many of the issues that stem from the disruption of habitat connectivity are common regardless of where a physical barrier is built. And just as habitat connectivity can have downsides (see doi:10.1093/biosci/biv021), the physical "thickening" of international boundaries with walls and fences can have unintended positive effects, too. A border fence in

southeast Mongolia is one possible example, explains Linnell. There, the Asiatic wild ass is effectively protected in Mongolia and may benefit from being prevented from crossing into China, where there is illegal hunting of this imperiled species. Other fences between countries and war-torn neighbors—such as Syria or Afghanistan—help reduce the exposure of wildlife to poaching, explains Linnell. More familiar, however, are the negative impacts of habitat loss, degradation, and fragmentation caused by barriers. These effects can be further heightened by disturbance from the often-increased levels of human activity at borders.

This ferruginous pygmy owl in Sonora, Mexico, is one of many species whose habitat is adversely affected by human-built barriers. Photograph: Aaron Flesch.

A wall of wildlife problems

Along about 700 miles of the US–Mexico border—over one-third of its length—there are already physical barriers. These vary from a wall of vertical steel posts to wire fencing to low-height vehicle barriers.

Flesch and five collaborators investigated the potential effects of a border wall on pygmy owls and desert bighorn sheep, publishing their study in *Conservation Biology* in 2009. In the borderlands, pygmy owls tend to be in habitats where there are both woodlands and saguaro cacti. This vegetational co-occurrence is spotty. So is the distribution of owls. Two or three owls might be separated from their nearest neighbors by 20 km, explains Flesch. "Local populations blink on and off like Christmas lights," he explains, referring to what ecologists call metapopulation dynamics. If a barrier is put in place, the result may be that some patches have insufficient recolonization in the event of a drought or disease, meaning that they may blink off—but not on again.

As for bighorn sheep, nine populations move between different sides of the border. Existing in small, fragmented groups like the owls, their ability to transit between groups is important to their continued viability. These owls and sheep were two species for which researchers had data, explains Flesch. If a border wall is constructed along the full length of the US–Mexico border, many other species are likely to be negatively affected, he says.

Flesch believes that there is widespread public misunderstanding about a potential border wall's impacts on wildlife. "The general public and the media hear 'border wall' and think, 'oh, that's horrible aesthetically' and it's going to cause some localized disturbance of the hydrology and vegetation clearing and habitat loss," he says. The public perceives mainly local effects of the wall, but they lack an understanding of population biology concepts, Flesch suggests, such as the need, in naturally fragmented environments, for organisms to move between patches to persist over the long term.

Movement among patches is particularly relevant in the naturally patchy border areas between Mexico, Arizona, and New Mexico. Here, mountains rising from lowland valleys create "sky islands"—the Madrean archipelago—harboring rich biodiversity. Interpatch movement is important for the region's native species, large and small.

Based at the US Geological Survey's Arizona Cooperative Fish and Wildlife Research Unit and the University of Arizona in Tucson, conservation geneticist Melanie Culver has examined the connectivity of many borderland species, including the endangered flat-tailed horned lizard, the Chiricahua leopard frog, bobcat, jaguar, and ocelot. "Genetics shows us that there is connectivity," she says. That is expected to change if impermeable wall structures are built.

"We were worried about this in 2008 and 2009 when the previous wall went in," says Culver. But during the construction of that wall, the US Fish and Wildlife Service led collaborative efforts with other agencies and universities to talk to Border Patrol and Homeland Security. "We actually went out several times and toured the wall and talked to them about possible mitigation efforts," she says. "There were cultural concerns, habitat concerns, water concerns… and all of these discussions resulted in some level of mitigation efforts, which was really a positive thing," she says. For example, of the existing wall, much of it is a barrier only to vehicles, a design that is permeable to large and small wildlife.

If a newer, expanded border wall cuts off wildlife populations, the result will be closed populations. Closed populations lose genetic variation because of a random sampling effect. Not every allele from parents ends up represented in their offspring, so over time, a population loses alleles. That loss of genetic diversity does not matter if you have an open population, explains Culver, because migrants bring new genetic variation that replenishes random loss. But in a closed population, it is a different matter. "We saw what happened to the Florida panthers," she says. Over time, closed populations suffer as a result of inbreeding depression. Such concerns have sparked legal action. In April, the Center for Biological Diversity and Representative Raúl M. Grijalva, (D-AZ), a member of the House Committee on Natural Resources, filed a lawsuit to block the border wall until an environmental impact study, including the wall's effects on endangered species, is completed.

But even without a physical barrier like a wall or fence, the security presence associated with an international boundary can have significant impacts on wildlife, explains David Christianson, also of the University of Arizona.

"That's a big part of border enforcement that I don't think people appreciate," says Christianson, who studies the endangered Sonoran pronghorn. "Even when there isn't a physical wall or much of a barrier, they are actively engaged in enforcing the law through patrols." Active patrols by US Customs and Border Protection agents extend many tens of miles into the US side of the border, he explains. Those patrols include travel through National Monument and National Wildlife Refuge lands. Border Patrol personnel use the roads, but they also "go off road a fair amount," he says, "right in the middle of this endangered species habitat."

Pronghorn are doing fairly well across the border in Mexico, Christianson explains. He has monitored animal behavior using cameras placed at artificial water sources.

Melanie Culver (1), of the University of Arizona, and project manager Susan Malusa check camera traps at their study site. Photograph: Buzz Conover.

Measuring the direct impacts of border activity on the population viability of pronghorn is "incredibly difficult," says Christianson. His studies have thus far focused on short-term behavioral responses. From preliminary radio-collar and camera-trap data, he has learned that pronghorn do not frequently go near the border.

So even without a wall, the activity associated with cross-border movement and border activity may split populations and reduce their connectivity, he says. "A physical wall may not make much difference for wildlife like the pronghorn if other forms of human disturbance have preceded it," he explains. A physical wall may be just another incremental barrier in a separation that already exists.

Surprisingly, one recent study of native and invasive mammal species provides evidence that nonhumans may be affected more than humans in terms of movement restrictions resulting from a US–Mexican border wall. Working at several protected areas within the Madrean Archipelago at four sites where there is already at least 1 km of 4- to 5-m-tall steel barrier, Jamie McCallum, consultant at Transfrontier International Limited in London, and colleagues at the Zoological Society of London used camera traps to observe mammal presence and absence, including humans. Between May 2010 and March 2011, using 36 camera traps, they collected presence–absence data for 17 native and nonnative mammal species, including deer, skunk, black bear, bobcat, cattle, domestic dogs, and horses, plus humans (characterized by visual clues as being law enforcement, smugglers, undocumented migrants, and others).

Characterizing the camera-trap locations as porous (without barriers), nonporous (having barriers), or at barrier ends (the first 500 m of open territory after a barrier), they examined "trap rates" for each species. Humans were captured in 283 photographs, from which 726 individuals

Camera traps of pumas (left) and coati (right) suggest that border barriers impede the movement of these two species—but these same traps captured images showing that such barriers are less effective in stopping the flow of humans. Photographs: University of Arizona/US Fish and Wildlife Service (puma); Jamie McCallum, Transfrontier (coati).

were identified. Data analysis of the native species revealed that puma and coati were more likely to be found in porous zones, suggesting that walls impeded the crossing ability of both of these animals, despite their highly contrasting body sizes and home ranges. Photographic data indicated no difference in the probability of presence of human smugglers and undocumented migrants at walled versus unwalled zones.

McCallum was surprised that the porosity of the wall did not affect the presence of people. "I thought it would have at least some kind of trace of an effect, even if it wasn't a statistically significant finding. But it didn't appear to," he says.

Another layer to the complex impacts of border structures on wildlife involves climate change. In the water-starved habitat between the southern United States and Mexico, climate change means changing landscapes, vegetation, water regimes, and wildfire frequency. "And for animals that are mobile like pronghorn, those things are not too bad as long as you can keep moving," says Christianson. But if in the future, their movement is constrained to a small geographic area, they may struggle. It is a conflict affecting many species in the face of climate change. There are limited options. "When things change, you can adapt, you can move, or you can die," says Christianson. "If you can't move and adaptation occurs over a very slow evolutionary timescale," he adds, "then the only option is die."

Dying because you cannot move from place to place is one concern. Dying as a direct result of a wall or border fence is another. In regions of the world beyond the United States and Mexico, border structures erected to stem the flow of human migrants are also having detrimental effects on wildlife, sometimes with outright mortality.

Seeing beyond walls

The formation of the European Union has generally led to international boundaries becoming more open and less visible. There, wolves have dispersed across the landscape. Aided by rewilding schemes, wolves have been moving into areas of Europe where they had been rare or absent for over half a century. As Linnell explains in his coauthored paper in *PLOS Biology*, the large spatial requirements of wolves and other carnivores have conferred flagship status to these animals as beacons of transboundary conservation. On paper at least, the European Union has formal guidelines regarding transboundary cooperation within its Habitats Directive. Nevertheless, ironically, alongside the recent emergence of transboundary cooperation as a research focus and conservation paradigm, Europe, too, has begun erecting border fences.

Many antirefugee fences were constructed in 2015 as "emergency measures" in response to the thousands of people fleeing conflicts in Syria, Afghanistan, Iraq, and the Horn of Africa. And although many conservationists were quick to condemn the fences on humanitarian grounds, media-circulated images of red deer ensnared and killed by the fencing wire also raised awareness of the biodiversity impacts of this border "thickening." This concern continues. A border-security fence now being constructed between Slovenia and Croatia will separate contiguous populations of bears, lynx, and wolves, with population impacts that are unlikely to be positive. The lynx population along this border region, for example, is already small and suffering the effects of inbreeding, say Linnell and coauthors.

And it is not just physical barriers that make international borders a unique challenge for conservation biologists; cultural factors also matter. When it comes to the management

of transboundary ecological communities, by definition, more than one national jurisdiction is involved. That means that efforts to mitigate the effects of barriers at borders—be they static physical walls or dynamic human and technologically monitored barriers—come with different socioeconomic pressures, environmental laws, and enforcement capacity.

Along with plenty of reasons for concern about growing border infrastructure and its impacts on biodiversity, there is also reason for hope. A subdiscipline of conservation biology focusing on transborder issues has begun to gain momentum. One researcher working in this area is Martin Dallimer, at the University of Leeds in England. Dallimer became intrigued by cross-boundary issues when working on the conservation of shorebirds such as the Eurasian curlew on agricultural lands in the United Kingdom. Shorebirds do not spend all of their time on any one farm; they move between them. So "farmers were making decisions about what they were doing with their particular areas of land, but the impacts of their decisions were quite dependent on what other farmers were doing as well," he explains. Dallimer realized that this was a microcosm of what happens at larger scales, like across international boundaries.

Dallimer and coauthor Niels Strange, of the University of Copenhagen, explain some of the fundamentals of cross-border conservation challenges in a 2015 paper in *Trends in Ecology and Evolution*. One key concept they underline is that when ecosystems or species are shared across international boundaries, "you get more biodiversity per dollar spent if you coordinate across boundaries," explains Strange. That efficiency of scale has successful precedents in places such as Waterton-Glacier International Peace Park, which spans the border of the United States and Canada. This park, according to a recent International Union for Conservation of Nature report on transboundary conservation, is one example of a successful international collaboration and economy of scale that has helped conserve grizzly bears.

A more unlikely and still-fragile success story of transborder conservation is that of Africa's Virunga National Park in the Democratic Republic of the Congo, bordering Rwanda and Uganda and protecting the world's critically endangered population of mountain gorillas. As Great Ape Survival Partnership Programme Manager

International borders are not the only places where decision-making in a landscape divided by barriers affects wildlife. University of Leeds researcher Martin Dallimer investigated how decision-making by individual farmers affected shorebirds across a wider region, such as the Eurasian curlew that frequently crosses boundaries within English farmland. Photograph: Martin Dallimer.

Further reading.

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at the United Nations Environment Programme Johannes Refisch says, the cross-border relations involved in protecting this species—reversing its decline to initiate an upswing—have been very difficult given the region's violent civil wars. During clashes between 2003 and 2007, some 1.3 million people were killed directly or indirectly as a result of the region's armed conflicts, including more than 150 park rangers in Virunga National Park. Nevertheless, despite recurring and bloody conflicts here, cross-border cooperation for conservation continued.

"Even though that was a very difficult period, we managed to bring the technical people together… so that at a low political level, we kept some kind of a cooperative spirit," says Refisch. Even though there was no political backup at a high level because of a communication breakdown among warring regions, at a lower level, antipoaching patrols still kept in contact across borders, he explains. Indeed, low-level political and grassroots cooperation can be a key mechanism for collaboration under difficult higher-level political circumstances. Granted, the Virunga Park is in a region where the international border is not delineated by a hard physical barrier. Nevertheless, that primate conservation could still be achieved despite the seemingly insurmountable challenges of a brutal civil war provides hope for collaborative conservation across the changing US–Mexican border.

But research has some catching up to do. From the perspective of biodiversity conservation, the impacts of border structures have, until very recently, been largely ignored. That is perhaps because most conservation-biology studies are conducted in North America and Western Europe, where border structures, until recently, have not been much of an issue, suggests Linnell. The paucity of research from Central Asia and the Middle East may be because these sensitive, secretive border areas are off-limits to researchers. "It's hard to study things that don't officially exist or where there is no public information on their location or structure," he says. Secrecy is also an issue in North America. Uncertainty about where the wall was going up next was a methodological challenge for Jamie McCallum's 2010–2011 US–Mexican border study. Within his study area, "literally, these guys arrived overnight and started building a wall," he says. Because of tight security, the research team never knew which section would be built next. So McCallum designed an experiment that tested differences across space rather than time, because secrecy made direct before–after comparisons impossible.

Funding to study the often-negative impacts of security structures, not surprisingly, is also difficult to secure. But Linnell is hopeful that media coverage of the biodiversity impacts of border walls and fences will stimulate new research, especially in European countries, "where the environmental impacts of such structures cannot simply be brushed under the carpet or hushed up," he says.

When it comes to international borders, Refisch draws insights from his work in the emerging field of environmental peace building, which integrates the management of natural resources into sustainable conflict resolution between adversaries in regions affected by conflict. "Of course, one has to regulate certain things, but wall building is pretty much against the general vision that collaboration

Mountain gorillas in the Virunga National Park, Democratic Republic of the Congo. Antipoaching patrols from warring factions in this international border area are managing to cooperate to protect the gorillas. Photograph: Johannes Refisch.

is good for everybody," he says. Building a wall, Refisch says, is "not a great vision."

McCallum's work on sections of the already completed US–Mexican border wall has led him to similar conclusions. "As a measure to achieve what it's set out to, it is the worst of all worlds. It doesn't stop people, but it does disrupt many other species very, very significantly," he says.

If the wall is completed, it will create a considerable biodiversity conservation challenge—one unlikely to disappear anytime soon. But there is reason to hope that while one country builds walls, international human ingenuity will build biodiversity bridges and wings.

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