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Ecosystem services across borders: a framework for transboundary conservation policy

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Ecosystem services across borders: a framework for transboundary conservation policy

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International political borders rarely coincide with natural ecological boundaries. Because neighboring countries often share ecosystems and species, they also share ecosystem services. For example, the United States and Mexico share the *provisioning service* of groundwater provided by the All-American Canal in California; the *regulating service* of agave crop pollination by long-nosed bats; and the aesthetic value of the North American monarch butterfly, a *cultural service*. We use the Millennium Ecosystem Assessment (MA) to elucidate how drivers in one country can affect ecosystem services and human well-being in other countries. We suggest that the concept of ecosystem services, as articulated by the MA, could be used as an organizing principle for transboundary conservation, because it meets many of the criteria for successful transboundary policy. It would frame conservation in terms of mutual interests between countries, consider a diversity of stakeholders, and provide a means for linking multiple services and assessing trade-offs between uses of services.

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International political borders rarely coincide with natural ecological boundaries. Political borders traverse ecosystems and cross watersheds. Many species of mammals, reptiles, birds, and insects regularly migrate across international borders (López-Hoffman *et al.* 2009). When neighboring countries share ecosystems, species, and ecosystem processes, they also share ecosystem services. Because the well-being of humans depends on the services provided by ecosystems (Daily 1997), when countries share such services, the welfare of their citizens is linked.

We present three case studies of ecosystem services shared by the United States (US) and Mexico to highlight the need for strategies to sustainably manage transboundary services. We suggest that the concept of ecosystem services, as developed by the Millennium Ecosystem Assessment (MA), could be used as an organizing principle for transboundary conservation, because it meets many criteria of successful transboundary policy: it frames conservation in terms of mutual interests, considers a diversity of stakeholders, and provides a means for linking multiple services and assessing trade-offs between uses of services.

While this is not a review of US–Mexico transboundary environmental policy, the discussion is timely, given the recent construction of a border wall that divides the two countries (Córdova and de la Parra 2007). At this time, it is particularly important to understand how the ecosystem services shared by the two countries transcend the border wall, and even the border region itself.

In a nutshell:

- Neighboring countries share ecosystem services
- Actions and policies in one country can affect ecosystem services and human well-being in another
- The US and Mexico share provisioning services (such as water), regulating services (such as crop pollination), and cultural services of migratory species (such as monarch butterflies)
- The transboundary services shared by the US and Mexico extend far beyond the border region
- The Millennium Ecosystem Assessment framework should be used as an organizing principle for transboundary conservation policy

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Conceptual framework

The MA is an international initiative to elucidate the relationship between ecosystems and human well-being. To characterize this relationship, the MA developed a conceptual framework for evaluating the complex interactions between ecosystems, the services they provide, and human quality of life (ie basic material for a good life, health, positive social relations, and security; Figure 1). The MA identifies two types of drivers of ecosystem change: indirect (ie social transformation, such as population growth, technology, and lifestyle) and direct (ie manipulation or management of ecosystems). We have adapted the MA to show how drivers in one country can affect ecosystem services and human welfare in a neighboring country (or in both countries, and not just in the

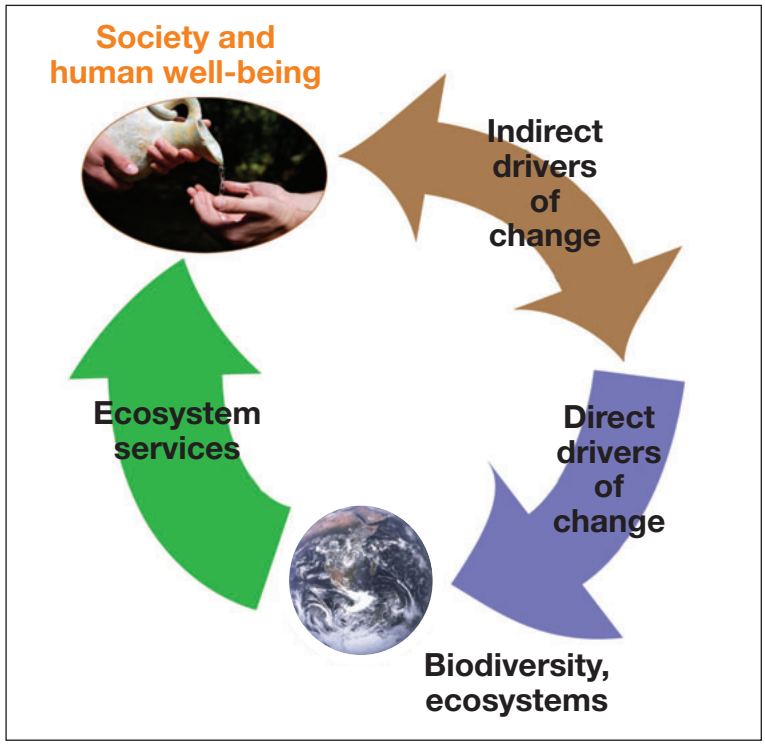

Figure 1. *The MA (2003) framework, modified from the original to emphasize the relationship between indirect and direct drivers, ecosystems, and the services they provide, and human society and well-being. Image credits: © J Pauls/www.iStockphoto.com (top inset), NASA/NSSDC (bottom inset).*

border zone) and how stakeholder interventions may have consequences across international borders (Figure 2).

The MA identifies four types of ecosystem services. *Provisioning services* are material benefits to humans, such as water or food. Processes such as pollination and disease control are described as *regulating services*. Biodiversity maintenance and nutrient cycling are *supporting services*. *Cultural services* are those aspects of species and ecosystems that provide humans with recreational, spiritual, or religious experiences (MA 2003).

Using existing data from published research, including data from governmental and non-governmental organization (NGO) databases, we have assembled three case studies of ecosystem services shared by the US and Mexico: (1) the *provisioning service* of shared groundwater provided by the All-American Canal in California; (2) the *regulating service* of agave crop pollination by long-nosed bats; and (3) and *cultural services*, such as the aesthetic value of the North American monarch butterfly.

Case studies

Provisioning services

The All-American Canal (AAC), constructed in 1942, diverts water from the Colorado River to California's Imperial Valley (Figure 3). Annually, millions of cubic meters of water seep from the unlined dirt canal, filtering into an aquifer beneath Mexico's Mexicali Valley. The leaked water accounts for 10–12% of the aquifer's annual recharge (Bureau of Reclamation 1994). This is an unintended addition to Mexico's official Colorado River allotment under the 1944 Water Treaty. For 60 years, this leaked water has provided substantial economic benefits to people living in the Mexicali Valley (Cortéz-Lara and Garcia-Acevedo 2000; Sánchez Munguía 2006). In addition, the seepage has created new habitats that support biodiversity; 6000 ha of wetlands have formed on Andrade Mesa, 3500 ha of which are in Mexico. The wetlands provide critical habitat for endangered and protected species, including the Yuma clapper rail (*Rallus longirostris yumanensis*, endangered in the US), the large-billed savannah sparrow (*Passerculus sandwichensis rostratus*, protected in Mexico), the gull-billed tern (*Gelochelidon nilotica*, a "Species of Special Concern" in California), and at least three other species that rarely breed elsewhere (Hinojosa-Huerta *et al.* 2002).

However, on the US side of the border, for years, heavy water users have called for the US Bureau of Reclamation to stem the transborder flow of water into Mexico. To supply more water to the city of San Diego, the Bureau is lining the AAC with cement, which will reduce annual water seepage by 83.5 million cubic meters. Although the Bureau's Environmental Impact Assessment considered the effect on wetlands in Mexico, its recommendations only addressed wetland mitigation in the US (Bureau of Reclamation 2006).

In 2005, a partnership between Mexican business and civic leaders and two US environmental NGOs filed a lawsuit in the US district court, asserting that lining the AAC would make the aquifer "completely unusable" for the 1.3 million residents of the Mexicali Valley, and that it would harm the local economy, destroy important wetlands, and negatively impact associated wildlife in Mexico (California Water Reporter 2006). In July 2006, the court dismissed the lawsuit, asserting that the protections of the US Constitution and Fifth Amendment do not apply to aliens outside US territory and that disputes over international water treaties should be resolved by diplomatic means (California Water Reporter 2006). In mid-2007, the Bureau of Reclamation began lining the AAC.

There are currently no adequate means for dealing with groundwater conflicts on the Mexico–US border. The 1944 Water Treaty mandated that the binational International Boundary and Water Commission (IBWC) distribute the surface waters of the Colorado River, but did not address groundwater. In 2006, the Mexican section of IBWC formally opposed the lining of the AAC, but it was powerless to intervene because the canal lies wholly within the US. Differences in water management, historically federal in Mexico and state-level in the US,

(Mumme 2000) and the "invisible" nature of groundwater (Ingram 2000) have also contributed to the lack of binational groundwater management. In 2007, the US Congress passed legislation promoting cooperation between appropriate entities in the US and Mexico for mapping and modeling priority transboundary aquifers (House Bill 469, Senate Bill 214, 109th Congress). It is possible that this act could eventually morph into a binational groundwater treaty, to address problems such as those posed by the AAC.

In this case study, the indirect drivers of the reduction in water supply to Mexico are San Diego's growing population and a US lifestyle of intensive water consumption. The actions of parties on both sides of the border affected those on the other side; stakeholders in the US will create water shortages in Mexico by lining the canal, while those on the Mexican side participated in a lawsuit, filed in the US, in an attempt to protect their ecosystem service.

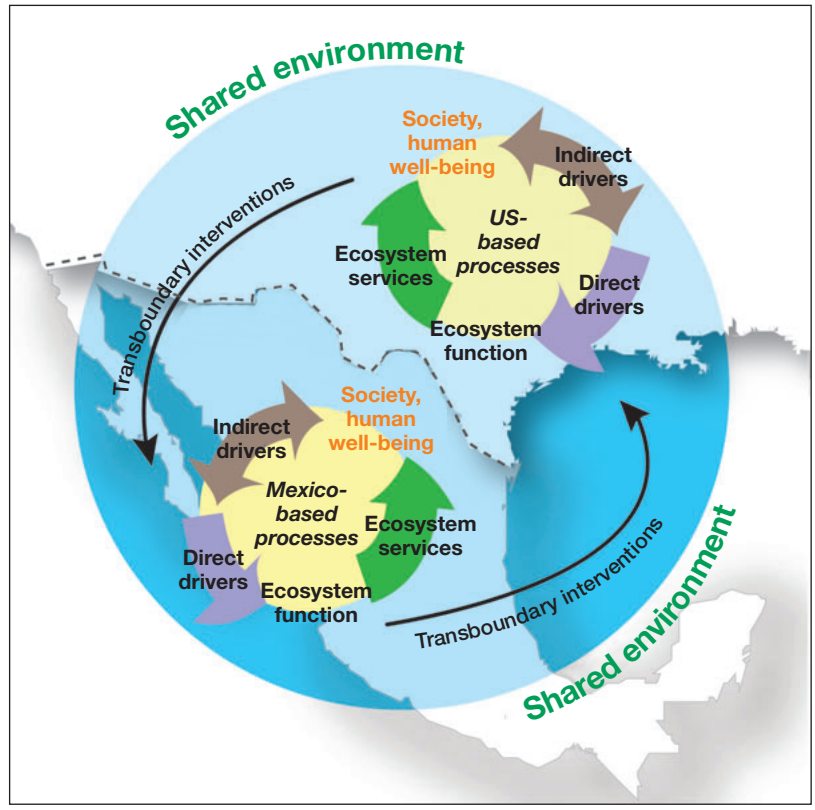

Figure 2. *The MA (2003) framework, adapted to explain transboundary ecosystem services shared by the US and Mexico. Two drivers of ecosystem change, indirect (ie socioeconomic factors such as population level, technology, and lifestyle) and direct (ie direct manipulation or management of ecosystems) impact ecosystem components and processes, in turn affecting ecosystem services. In a transboundary situation, people in one country can intervene across borders, affecting the delivery of ecosystem services in another country.*

Regulating services

Two species of endangered, long-nosed bats (genus *Leptonycteris*) are the principal pollinators of blue agave (*Agave tequilana*), the main ingredient of tequila. The regulating services provided by these bats are therefore important for healthy agave crops (Arita and Wilson 1987; Eguiarte and Arita 2007; Figure 4). Mexican corporate producers currently propagate agave plants vegetatively, rather than allowing natural pollination and reproduction to take place (the agave heart, which is cooked and distilled, has a higher sugar content if the plant is prevented from flowering). Today, most large agave plantations cultivate only one or two genetic varieties. In the late 1980s, and again in 1996–1997, the genetically homogeneous crops were devastated by pathogens, resulting in substantial economic losses (Valenzuela-Zapata and Nabhan 2003). Higher genetic diversity is related to disease resistance; if bats were allowed to pollinate agave naturally, cross-pollination between different plants would lead to higher genetic diversity and increased pathogen resistance (Arizaga *et al.* 2002). Unless measures are taken to increase the genetic diversity of agave crops, they will continue to be devastated by pathogens (Valenzuela-Zapata and Nabhan 2003).

Several direct drivers threaten the survival of long-nosed bats. Many bats of these species spend the summer in caves in northern Mexico and the southwestern US, from Texas to Arizona (Medellín and Walker 2003). Millions have been burned, dynamited, or barred from their roosts by ranchers who mistake them for vampire bats. Bat caves have also been destroyed by urban development, highway construction, and vandals (Walker 1995). In the 1980s, a colony in Texas' Big Bend National Park declined in numbers by 90% (BCI 1988). Until the US Border Patrol installed fencing, long-nosed bats in the Cabeza Prieta National Wildlife Refuge in Arizona were being driven from their caves by human smugglers transporting undocumented migrants across the border (J Montoya pers comm).

In Mexico, large corporate tequila producers and small traditional artisans are pursuing different types of interventions. Although corporate producers are aware of the importance of genetically diverse agave crops, they are seeking to replace bat pollination services with technological solutions (Dalton 2005). Small-scale, artisanal tequila producers use many genetic variants of *A tequilana*, as well as other agave species, such as *Agave angustifolia* (Colunga-GarcíaMarín and Zizumbo-Villarreal 2006). They are interested in collaborating with conservation biologists to develop long-term solutions to bat conservation in both Mexico and the US (R Medellín pers comm). In this example, several indirect drivers – increased urban development and highway construction due to population growth in both countries, cultural fears of bats, and the consequence of undocumented workers

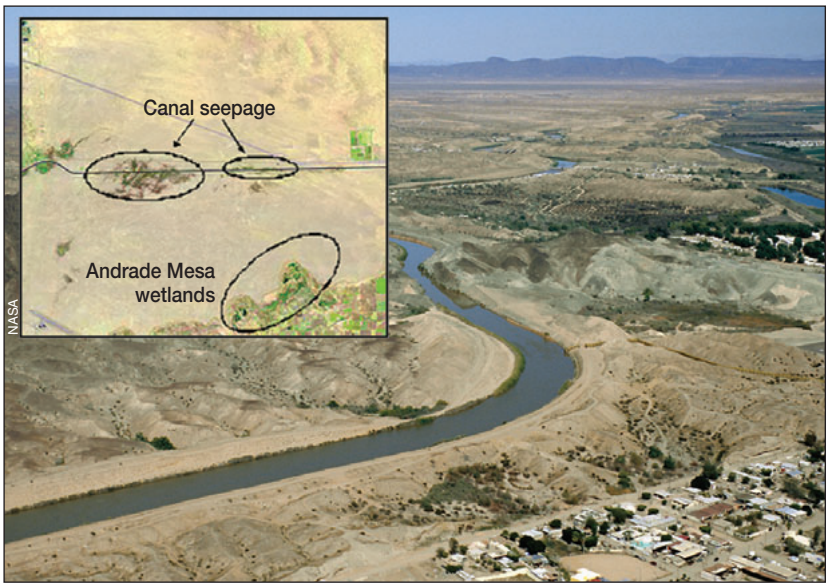

Figure 3. *The All-American Canal. In the Landsat image (inset), seepage from the canal and the Andrade Mesa wetlands in Mexico are labeled. Inset modified by A Hinojosa.*

crossing the border – have caused the destruction of bat habitat, the direct driver of declining long-nosed bat populations (Medellín 2003).

Cultural services

One of the most profound examples of aesthetic fulfillment from nature is the sense of awe that people from Canada to Mexico experience when they witness the extraordinary migration of the monarch butterfly (*Danaus plexippus*). Every fall, more than 100 million monarch butterflies migrate from Canada and the US to southern Mexico, alighting in oyamel fir (*Abies religiosa*) forests on ten small mountaintops. Over the past 10 years, ecotourism in Mexico has increased, as more people are drawn to the spectacular sight of forests laden with butterflies (Figure 5).

Throughout their range, however, monarch butterflies are in jeopardy. Their winter habitat in Mexico is threatened by illegal logging in the fir forests (Galindo-Leal 2006). In the species' US and Canadian summer grounds, there are indications that pollen from corn transgenically engineered to express insecticidal proteins may harm butterflies and other insects (Jesse and Obrycki 2000). In Canada, milkweed (*Asclepias* spp), the monarch's primary host plant and food source, is considered a noxious weed, and has been designated for eradication. In the US, intensive agricultural practices have reduced native vegetation around fields, inducing the loss of the milkweed plants that fuel the butterflies' fall migration to Mexico (Brower *et al.* 2006).

To date, monarch conservation efforts have largely focused on Mexico. In 1986, the Mexican government proclaimed the monarch overwintering sites as a Biosphere Reserve and prohibited logging. Using a direct payment approach, US and Canadian NGOs recently began paying local people to forgo logging in forests where the butterflies spend the winter (Missrie and Nelson 2005). Despite these efforts, deforestation seems to be increasing in the reserve (Galindo-Leal 2006). Until recently, relatively less attention has been given to protecting the butterflies in their summer sites in the US and Canada, although NGOs have been encouraging the cultivation of milkweed plants by providing gardeners with seeds and instructions for creating butterfly gardens (Monarch Watch 2007).

In Mexico, the indirect drivers of declines in monarch butterfly numbers are poverty and constrained law enforcement, resulting in illegal logging. In the US and Canada, intensive agricultural practices and weed-control policies are linked to declining butterfly populations.


R González Chauvet

Figure 4. *A long-nosed bat* (Leptonycteris yerbabuenae)*, a pollinator of the agave plant.*

■ Scale and range of transborder services

These case studies demonstrate that transborder ecosystem services range far beyond political boundaries. The North American Agreement on Environmental Cooperation (NAAEC), a provision of the North American Free Trade Agreement (NAFTA), delineated the US–Mexico border region as a 100-km-wide band on either side of the political boundary (Varady *et al.* 1996). The 200-km-wide strip, designated as a zone for environ-

mental infrastructural investment, has thus been commonly assumed – mistakenly, we believe – to represent the limit of the ecological connection between the two countries. In fact, most studies of the transborder environmental connections between the US and Mexico have focused on the geographically narrow border region (Herzog 2000; Fernandez and Carson 2002; Hoffman 2006a).

In our first example, the environmental impact of shared canal water is geographically limited by the physical drainage basin, but the bat and butterfly examples clearly demonstrate that the services shared by the US and Mexico range far beyond the border (Figure 6). We suggest that the scale of ecological connection between countries should be delimited by the size of the ecosystem or the scale of the ecological processes and services in question. For services provided by migratory species, the scale is determined by the species' distribution range.

We have presented only three case studies of ecosystem services shared by the US and Mexico. However, there are other, equally compelling examples. For example, the Santa Cruz River, which flows northward from Nogales, Mexico, is critical for biodiversity in the Tumacacori region of Arizona. Some Arizonans fear that Nogales might follow the example of San Diego and stop the transboundary flow of water. In addition, the conservation status in Mexico of the Brazilian free-tailed bat (*Tadarida brasiliensis*) is critical for cotton crop pest regulation in Texas and Arizona (Cleveland *et al.* 2006).

MI Ramirez

Figure 5. *Monarch butterflies roosting in Michoacán, Mexico.*

■ Discussion

The AAC, long-nosed bat, and monarch butterfly case studies demonstrate that ecosystem services shared by the US and Mexico are fundamental for human well-being in both countries. Given the importance of ecosystem services shared by neighboring countries, strategies to sustainably manage transboundary services are urgently needed. The concept of ecosystem services as articulated by the MA could be used as an organizing principle for transboundary conservation, because it meets many criteria of successful transboundary policy: it frames conservation in terms of mutual interests, considers a diversity of stakeholders, and provides a means for linking multiple services, assessing trade-offs between uses of services, and monitoring changes in services (sensu Susskind *et al.* 2002; Wolf 2007).

Mutual interests

Scholars of transboundary environmental policy agree that successful policy is best achieved when the discussion is framed in terms of mutual interests instead of rights and needs. They point out that something in the mutual interest of two countries gives both countries incentives to work together, rather than against one another (Mumme 2000; Susskind *et al.* 2002; Hoffman 2006b; Wolf 2007). The notion of interest – importance to human well-being – is inherent in the ecosystem service concept (MA 2005). If transboundary conservation problems were framed as the conservation of shared ecosystem services, as in Figure 2, the discussion would be transformed into one of mutual interest between countries.

The monarch butterfly is a timely example of transboundary conservation being reframed as one of mutual interest between nations. Although drivers of change in monarch populations have been occurring in all three countries, until recently, the most important conservation interventions focused on Mexico and on the Mexican government's failure to halt logging in the monarch's winter grounds (Missrie and Nelson 2005; Galindo-Leal 2006). However, in April 2008, in recognition of the monarch's status as a cultural symbol throughout North America, the trilateral Commission for Environmental Cooperation (CEC) and World Wildlife Fund-Mexico launched an effort to identify drivers of monarch decline and prioritize areas for habitat conservation throughout the entire North American migratory flyway (CEC 2008). In the monarch example, the mutual

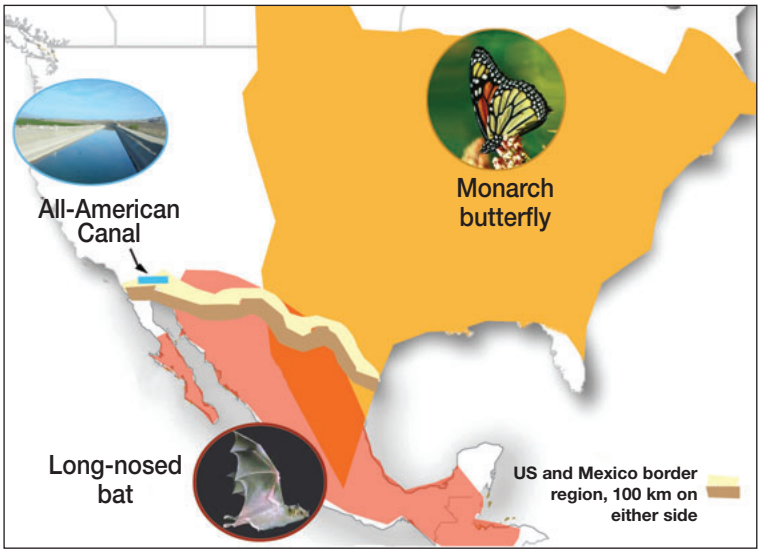

Figure 6. *Alternative perspectives on the conceptual dimensions of the US–Mexico border: the 200-km-wide border strip is shown in brown and beige; the potential area of influence of water from the All-American Canal is in blue; the long-nosed bat species distribution is rose colored; and the monarch butterfly range is in gold. Geographic representations not to scale. Image credits: G Smart/USFWS (butterfly inset), © MD Tuttle, Bat Conservation International (bat inset).*

interests of the US and Mexico in conserving the butterfly align; efforts to protect monarchs in one country will benefit stakeholders in all countries.

In the case of the AAC, it has been very difficult to reach agreements in the mutual interest of both countries that are considered fair and equitable by all parties (Mumme 2008). This is due in part to the nature of the service; because water is finite, efforts to increase water on one side of the border necessarily dictate a decrease on the other side. In such situations where binational interests do not align well, innovative approaches, such as new institutions, legal structures, or creative transboundary collaborations, may be used to find common ground.

A creative solution to the AAC situation might involve transboundary payments for ecosystem services. Stakeholders in the US and Mexico who are concerned about the loss of biodiversity in Mexico's Andrade Mesa wetlands could buy existing Colorado River water rights in Mexico, and dedicate the water to wetland protection. Mexico's national water law was recently amended to allow for "environmental use". Income from selling existing water rights might partially offset Mexican agricultural losses due to groundwater reductions. Two NGOs, the US-based Sonoran Institute and Mexico's Pronatura Noroeste, are using a similar approach to secure water for restoring the Colorado River delta (Zamora-Arroyo *et al.* 2008).

Multiple stakeholders

An advantage of using the MA as a foundation for transboundary environmental policy is that it recognizes that stakeholders differentially benefit from ecosystem services (Maass *et al.* 2005). In discussions of transboundary water policy, the interests of stakeholders within countries are often treated as homogeneous – the conversation is framed as "the US wants…" or "Mexico feels…" (sensu Wolf 2007). This masks the differing uses of and attitudes toward ecosystem services among groups of stakeholders. For example, in the agave pollination case study, corporate and small-scale tequila producers in Mexico value bat regulating services very differently; corporate producers are trying to replace pollination services, while artisanal producers are trying to protect bats and the ecosystem services they provide.

Interactions between services

A strength of the MA conceptual framework is that it considers interactions between ecosystem services and how they may depend on ecological and social processes operating at different spatial scales (MA 2003; Rodríguez *et al.* 2005). In most transboundary environmental policies, different types of issues are usually managed separately – for example, water issues are dealt with in water treaties and migratory species in migratory species treaties (Hoffman 2006b; Wolf 2007). Transboundary water policy scholars have begun to realize that water treaties that ignore other issues and resources either fail or result in suboptimal and inequitable arrangements (Wolf 2007). When linkages are made between water and other resources, creative solutions with greater benefits to stakeholders can be devised (Sadoff and Gray 2002). In a multi-service treaty based on the MA conceptual framework, the management of a fundamental provisioning service, like water, could be tied to the protection of regulating and supporting services. For example, a treaty might mandate that no changes in water provisioning could be undertaken without considering the effects on other types of services.

In the AAC case study, Mexican stakeholders attempted to tie the loss of provisioning water services to the loss of supporting services for bird habitat. In addition to claiming loss of property (ie water), their lawsuit also claimed that the canal lining would violate the US Endangered Species and National Environmental Policy Acts (NEPA) and the Migratory Bird Treaty by harming the Andrade Mesa wetlands. A 2006 US Congressional waiver prevented the district court from determining the merits of those claims. Had the underlying treaty considered the importance of water for other resources and services, concerns about the loss of wetland habitat might not have been so easily dismissed.

Trade-offs

The MA provides a framework for identifying the trade-offs between multiple uses of ecosystem services and

between uses by different stakeholders (Hassan and Scholes 2005; Maass *et al.* 2005; Rodríguez *et al.* 2006). In the AAC example, there is a trade-off in how water is used – currently, water is being allocated to agriculture and municipal uses in California to the detriment of supporting biodiversity in both the US and Mexico. For corporate tequila producers, there is a trade-off between production efficiency and susceptibility to pathogens – cloned agave plants have higher sugar contents but lower genetic diversity and increased susceptibility to pests.

Monitoring drivers of change

Given the importance of transboundary ecosystem services, mechanisms for monitoring the indirect and direct drivers that affect the provisioning of ecosystem services and human welfare across borders are needed. The MA provides an effective conceptual framework for monitoring drivers of ecosystem change (Hassan and Scholes 2005). It will be critical for the US and Mexico to monitor the drivers changing their shared environment. Although the case studies represent different types of ecosystem services, a common set of drivers is affecting the services and their delivery – growing human populations and concomitant urbanization along with land-cover changes and more intensive uses of land on both sides of the border. In the AAC example, increased water demands from southern California's growing population will decrease water supply in Mexico. In the bat and butterfly examples, urbanization as well as both intensive and extensive land use are degrading critical habitat supporting the service. In all case studies, land-use change in one country is affecting stakeholders in the other country.

■ Conclusion

We have used three examples from the US and Mexico to demonstrate that neighboring countries share ecosystem services. The water flowing across the US–Mexico border through rivers and aquifers provides vital provisioning and supporting services in both countries. Species such as bats and butterflies may migrate many hundreds of kilometers across the border, providing critical regulating and cultural services to people in both countries.

Given the importance of transboundary ecosystem services, strategies for managing shared services are urgently needed. The concept of ecosystem services, as articulated by the MA, could be used as an organizing principle for transboundary conservation. The MA provides a way of framing transboundary conservation in terms of mutual interest between countries. In some cases, the mutual interests of the countries will align well, as in the example of the monarch butterfly. In situations such as the AAC, the interests of the two nations are not so well aligned. In such cases, creative and innovative approaches to transboundary collaboration – new institutions and legal structures and payments for transboundary ecosystem services – are needed. Given the importance of transboundary ecosystem services to human well-being, it is in the interest of neighboring countries, such as Mexico and the US, to develop permanent, long-term strategies to equitably manage shared ecosystem services.

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