Annu. Rev. Energy Environ. 1999. 24:607–43

ENVIRONMENTAL ISSUES ALONG THE UNITED STATES-MEXICO BORDER: Drivers of Change and Responses of Citizens and Institutions

Diana M. Liverman
Latin American Area Center, University of Arizona, Tucson, Arizona 85721; e-mail: liverman@u.arizona.edu

Robert G. Varady
Udall Center for Studies in Public Policy, University of Arizona, Tucson, Arizona 85719; e-mail: rvarady@u.arizona.edu

Octavio Chávez
International City/County Management Association, Mexico Program, 44690 Guadalajara, Jalisco, Mexico; e-mail: ochavez@icma.org

Roberto Sánchez
Board on Environmental Studies, University of California at Santa Cruz, Santa Cruz, California 95064; e-mail: rsanchez@cats.ucsc.edu

Key Words pollution, conservation, NAFTA, social movements

■ **Abstract** The US-Mexico border region illustrates the challenges of binational environmental management in the context of a harsh physical environment, rapid growth, and economic integration. Transboundary and shared resources and conflicts include limited surface water supplies, depletion of groundwater, air and water pollution, hazardous waste, and conservation of important natural ecosystems. Public policy responses to environmental problems on the border include binational institutions such as the IBWC, BECC and CEC, the latter two established in response to environmental concerns about the North American Free Trade Agreement (NAFTA). Environmental social movements and nongovernmental organizations have also become important agents in the region. These new institutions and social movements are especially interesting on the Mexican side of the border where political and economic conditions have often limited environmental enforcement and conservation, and where recent policy changes also include changes in land and water law, political democratization, and government decentralization.

1056-3466/99/1022-0607$12.00

CONTENTS

INTRODUCTION

The border between the United States and Mexico provides a dynamic and complex example of the challenges of binational environmental management in the context of economic integration. The 2000-mile-long border is home to millions of people who share water, air, land, and ecosystems under very different institutional structures and in a variety of social conditions. Although scholars and policy makers have analyzed environmental issues on the border for several decades, the implementation of the North American Free Trade Agreement (NAFTA) in 1994 brought renewed attention to the region. NAFTA consolidated long-term trends in industrialization, agricultural intensification, and urbanization of the border region; catalyzed environmental groups and other social movements; and resulted in the establishment of several new institutions to manage the border environment. Most scholars and agency officials consider the "border" to be the region extending ~100 km north and south of the boundary, although others include all of the border states—California, Arizona, New Mexico, and Texas in the United States and

Baja California, Sonora, Chihuahua, Coahuila, Nuevo León, and Tamaulipas in Mexico (Figure 1; see color insert). The border environment is, of course, affected by many processes that originate and occur far beyond the 100-km boundary, in that air, water, and species move across much larger areas, and policies are made in jurisdictions beyond this narrow zone. The large majority of the population of the border area reside in urban areas. These urban centers lie at discrete points along the frontier and are generally isolated from each other and from other communities (Figure 1; see color insert). The neighboring governments, in their various border plans, consider that there are 14 pairs of border cities, with the largest and most prominent being San Diego-Tijuana, Nogales-Nogales, El Paso-Juárez, Laredo-Nuevo Laredo, and Brownsville-Matamoros.[1]

The United States-Mexico border provides a useful venue for analyzing several theoretical questions in environmental research, such as the role and effectiveness of environmental social movements and binational institutions, the political ecology of economic globalization, and the impacts of decentralization and democratization on environmental practices of local governments. The border also provides tremendous challenges for public policy in terms of designing effective institutions, resolving conflicts, and understanding public responses to free trade. In this paper, we discuss the range of environmental issues facing border communities and organizations and examine the driving forces that are transforming environment and society on the United States-Mexico border. The analysis is framed in terms of the interaction between institutional structures and individual actions, particularly the binational border institutions and environmental social movements. We begin with a brief overview of current environmental issues facing the border region, followed by an analysis of the historical and contemporary forces driving environmental change in the border region. The second part of the paper describes and analyzes the institutions and social movements that are managing and responding to these changes.

OVERVIEW OF CONTEMPORARY BORDER ENVIRONMENTAL ISSUES

Today, the border region is one of the most environmentally stressed areas in the world, posing many problems for both the United States and Mexico, especially for the people who live in the region (1–3). Potable-water supplies are scarce as increasing numbers of domestic, agricultural, and industrial users compete for limited and often polluted surface-water and groundwater resources. The region is significantly underserved by wastewater treatment facilities, and industrial hazardous wastes are commonly disposed of improperly or illegally into the

[1]The others are Calexico-Mexicali, Yuma-San Luis Río Colorado, Naco-Naco, Douglas-Agua Prieta, Columbus-Las Palomas, Presidio-Ojinaga, Del Rio-Ciudad Acuña, Eagle Pass-Piedras Negras, and McAllen-Reynosa. In all of these cases except San Diego-Tijuana, the Mexican cities are far larger than their US neighbors.

environment, threatening workers and residents in many communities. Air pollution from vehicular traffic as well as the burning of solid wastes and emissions from industrial sources pervades many areas, and the increasing encroachment and levels of pollution from human activities threaten the unique ecosystems and fragile lands of the region.

The physical geography of the border region poses many challenges for human development and environmental quality. The United States-Mexico border is generally characterized by a semiarid climate, although rainfall is higher toward both coasts. Throughout the area, precipitation can vary dramatically from one year to another, and evaporation exceeds precipitation for many months of the year, causing a soil moisture deficit.

The dry conditions mean that water supplies are insufficient and the potential for pollution dilution is limited. Many border communities rely heavily on the flow of rivers, such as the Rio Grande (known as the Río Bravo in Mexico), the Colorado River, and the Río Conchos, which originate in mountainous regions and political units far from the border. Mining, agriculture, urban development, and manufacturing depend on the pumping of fossil groundwater that is being depleted in many of the aquifers in the border region. High summer temperatures can promote disease and air pollution; cause stress to humans, crops, and animals; and increase energy demands for irrigation, refrigeration, and air-conditioning.

Competition Over Transboundary and International Rivers

Competition for the limited surface-water supplies from the major shared rivers, the Colorado and Rio Grande, is increasing as a result of expansion of agricultural irrigation in some areas (especially northern Mexico) and urban growth at many places along the border. These two rivers were fully allocated under historical water rights and international law, but overall use has increased as areas like Tucson, Las Vegas, and the agricultural and urban areas of the Río Conchos basin (tributary to the Rio Grande) have taken up their full allocations. The major use of water in all border states is for irrigated agriculture, which demands ~90% of available supplies in both California and Arizona. Although only ~18% of Mexico's agricultural land is irrigated, much of the irrigation is in Mexico's north; the six border states account for 43.5% of the country's irrigated land (4). Additional challenges and demands for the waters of these and other transboundary rivers such as the San Pedro and Santa Cruz are emerging as Indian tribes make claims for their water rights and consideration is given to the maintenance of instream flows to protect ecosystems and endangered species. Water-supply problems and conflicts result in crop failure, ecosystem damage, constraints on urban growth, and significant economic losses, as well as costly lawsuits and potentially violent conflict between neighbors.

Drought and Climate Change

Climate variability and climate change pose a major threat to water resources in the border region. Because interannual climate variability is high, river flows

fluctuate significantly from one year to another, and drought frequently causes problems for water use and institutional arrangements in the border region. For example, the recent 1993–1996 drought in northern Mexico and Texas drew down reservoirs to such low levels that agricultural production declined and conflicts arose between the United States and Mexico, Texas and New Mexico, and Nuevo León and Tamaulipas over shared river and reservoir resources (5). Droughts in the border region are often associated with La Niña conditions of below-normal sea surface temperatures in the Pacific (6). A study of historical drought on the Colorado River, using both instrumental and paleoclimate records, indicated that any return to the most severe droughts on record could result in the emptying of Lake Powell and low flows of <25% of average at Lee's Ferry (7). Global warming could also change the water supply in the border region. Several studies suggest that a doubling of greenhouse gas concentrations could bring warmer and drier climates to the already dry border area (6, 8). Although projections of temperature increases of up to 4°C over the next 50 years are fairly consistent, authors disagree about how precipitation and hydrology might change in a warmer world. For example, studies of how climate change would affect Colorado River flows suggest that flows could drop by as much as 40% (9). Other studies are more conservative but still indicate a drop in flows of 10%–20% (10, 11). Scenarios for the Rio Grande/Bravo also suggest reductions in flows under global warming (12, 13).

Groundwater Depletion

A number of border communities rely on groundwater, and aquifer depletion is a serious problem for several large cities, especially the El Paso-Juárez conurbation, in which 90% of water supplies comes from the severely overdrafted Hueco Bolsón and Mesilla aquifer (14, 15). Groundwater overdraft results in subsidence, higher pumping prices, disappearance of linked surface flows and ecosystems, and eventual water shortages as wells fail. The level of the Hueco Bolsón has fallen ~45 m since 1940; in some parts of Juárez, well levels are falling by 10 m/year. The city of El Paso projects that, at current rates, the aquifer will be exhausted by 2025, causing massive shortages in the region (16). Other aquifers under stress include the Edwards (Del Rio-Ciudad Acuña), Mimbres (New Mexico), San Pedro (Sonora-Arizona), and Imperial-Mexicali (California-Baja Norte) (17).

Water Shortages and Pollution in Cities and Colonias

Urban water demand is growing; in Arizona and Sonora, for example, municipal demand is expected to double in the next 10–20 years. Many communities on the Mexican side of the border still have inadequate access to safe drinking water. For example, only 64% of the residents of Nogales, Sonora, and 72% of those in Matamoros, Tamaulipas, are served by potable water (17).

Problems associated with water in these urban areas underlie the most serious environmental issues and draw the most public attention because of their implications for human health. These problems are of three types: those relating to quantity, i.e. shortages in supply and availability; those characterized by concerns

over quality, i.e. chemical and biological contamination of drinking water and water-creating natural habitats; and those having to do with wastewater management. In border cities, all three sets of issues are manifest and even exacerbated by the region's susceptibility to periodic bouts of drought and flooding. These concerns are particularly serious in the much larger, infrastructure-short Mexican communities. As elsewhere, the quantity and quality of water and wastewater are related to each other in a number of ways. Inadequate coverage by sewer systems accompanied by high leakage rates has been a persistent feature in these communities. In Mexican cities, the percent of population benefiting from wastewater-sewer service ranges from only 39% in Ciudad Acuña and 47% in Matamoros to 80% in Nogales and Mexicali (17). Of the wastewater that is collected, only a small proportion receives any treatment.

The emergence of colonias[2] has contributed to the sewerage problem that has been associated with a high incidence of intestinal diseases (18). Similarly, there are generally too few treatment plants, and those that function are usually overtaxed and in poor repair (19). The water supply systems in border communities also are in need of renovation and improvement; many were constructed early in the century and are subject to chronic leaks, equipment breakdowns, low maintenance budgets, and depletion of aquifers and surface water resources. Case studies, such as for the twin cities of Nogales, show that the insufficiency of these systems, threats from industrial pollution, contamination from solid and liquid waste, and the action of disease vectors all impact the state of human health (20).

Not surprisingly, the most serious problems are found in the colonias on both sides of the border. On the US side of the border alone, especially in Texas and New Mexico, it has been estimated that more than 1.5 million people live in 1500 colonias, with >50,000 people living in colonias in El Paso County alone (21). These communities originated as makeshift clusters on inexpensive, unzoned land settled by agricultural and industrial workers in the 1950s, and they now house a predominantly Latino population (22). Poverty and lack of services contribute to chronic and acute infectious health problems such as gastroenteritis, dysentery, and cholera in both the US and Mexican colonias. Additionally, colonias often have been settled above retired agricultural fields, small farms and dairies, or near contaminated wells. In such instances, residuals from pesticides, fertilizers, and animal waste can introduce carcinogenic compounds such as trichloroethylene [a volatile organic compound (VOC)] and nitrates, as well as other VOCs, inorganic compounds, and metals in drinking water (18).

Ambos Nogales (both Nogaleses) exemplifies a large, transborder urban agglomeration with a history of friendly relations between the neighboring cities. The overall water situation there is typical of that in other communities along the border and throughout the whole of Mexico. Municipal and state authorities not

[2]These are unplanned, low-income settlements (often situated on poorly accessible hilltops) that have sprung up to house the labor force for the maquiladora industry (described below) on the Mexican side and have been used as cheap, unserviced residences on the US side.

only have to confront the difficulty of guaranteeing supplies to residents but also must raise the efficiency of service, improve the financial solvency of their operations, ensure more equitable distribution of water to all social groups within the community, and extend the water treatment and wastewater collection services. The major sources of pollution in Ambos Nogales include bacteriological contamination from the Nogales Wash, a tributary of the Santa Cruz River (whose waters eventually flow to the Colorado River), and contamination from several wells used by public water trucks (23). In addition, seepage of nitrates, heavy metals, and VOCs from industry into soils underlying the aquifer affects the quality of urban water in both communities (18). Using forecasts of population growth based on trends during the previous decades, researchers have estimated that the population of Nogales, Sonora, will double from its 1990 population of about 110,000 to nearly 220,000 by the year 2010 and that, by the year 2020, the city will have 285,000 residents (the population of Nogales, AZ, also is growing, but that city is only a quarter the size of its Mexican neighbor) (23). The pressure to provide sufficient quantities of safe drinking water is particularly intense on the Sonoran side. Obviously, population increases on the projected scale will place severe demands on an already overtaxed system.

In Nogales, Sonora, 76% of the public water supply serves domestic users, with the remainder used by industrial, commercial, and service sectors (23). Losses from the system caused by at least 3000 illegal taps into the system are estimated by the Sonoran Commission of Drinking Water and Wastewater (COAPAES) to be 25% of the total supply. According to COAPAES, nearly 84% of all households receive potable water, although not necessarily during all 24 hours of the day. The agency maintains that the range in services for various areas within the city is from 67% to ~100%. In terms of hours of daily service, 32.3% of households receive water at all times, whereas 44.7% have it for $\leq$6 h/day. The COAPAES figures have been challenged by some observers who believe that they overestimate the level of service (23). Because public water supply remains irregular temporally and spatially, many residents obtain their water from private sources, most notably from pipas (trucks) that fill rooftop storage tanks. Those with higher incomes purchase expensive bottled water, sometimes from across the border. In either case, privately secured water is much more expensive than publicly provided water—an equity problem that pervades the entire border region (20).

Air Pollution

Urban residents of the border region are exposed to air pollution from a variety of sources, including automobiles and industry. Pollutants of concern to human health include particulates, sulfur dioxide, carbon monoxide, and ozone (17). Smelters and thermoelectric plants are significant regional sources of sulfur dioxide. Copper smelters in the Arizona-Sonora "Gray Triangle" were blamed for local respiratory illnesses and acid rain in the early 1980s (24), and, although the smelter in Douglas, Arizona, closed in response to economic problems, the Cananea, Sonora, smelter

has expanded its operation, and a newly built smelter in nearby Nacozari began operating in the late 1980s (25, 26). These increases in production have been in response to Mexican government policies and the world market for copper. United States sulfur dioxide standards are still exceeded in Douglas, AZ, and just across the border in Agua Prieta, near Cananea, and in Juárez downwind of the Asarco smelter in El Paso (17). Proposals to expand thermoelectric generation by coal at the Carbon II plant in Coahuila also have met with opposition from environmentalists concerned about local and regional pollution.

Several border cities are facing serious air pollution problems associated with the growing numbers and use of trucks and automobiles. In the El Paso-Ciudad Juárez urban zone, maximum monthly 1-h ozone concentrations (US standard of 0.12 ppm) are reached or exceeded every month between April and November (17). In the San Diego-Tijuana conurbation, ozone standards are reached or exceeded in January and from April to August (17). These cities also are considered nonattainment areas for sulfur dioxide. Most of the border cities exceed particulate-matter standards, mainly as a result of dust storms from unpaved roads and bare, sandy land. Mexico introduced lead-free gasoline only in recent years, and lead levels in children have remained high from both automobiles and smelters (27). Home heating and small industry also contribute to air pollution. For example, brick makers in Juárez have burned heavily polluting rubber tires for fuel, and paint shops and dry cleaners in Tijuana emit solvents into the atmosphere (27).

Toxics and Hazardous Wastes

Industrial development and agricultural intensification have increased the releases of hazardous or toxic substances on the border in the form of workplace contamination, community pollution, and ecosystem impacts (28). Some of the more serious risks include those from pesticides, heavy metals, and solvents, and from the illegal disposal and transfrontier shipments of wastes (29). There is also a toxic legacy of metals and solvents associated with wastes from mines and abandoned industrial or military facilities, especially on the US side of the border, where the Environmental Protection Agency (EPA) has identified>20 Superfund sites in the border region (17). On the US side of the border, the risks of pesticides to human health and ecosystems are of particular concern in intensive agricultural regions such as the lower Rio Grande Valley and the Imperial Valley (30). Laws passed in the United States in response to the publication of books such as Rachel Carson's *Silent Spring* (in 1963) reduced the use of the more persistent chemicals such as chlorophenothane (DDT), but overall pesticide use has increased to >1.2 billion pounds nationwide as a result of the search for higher yields and the shift toward growing cotton, fruits, and vegetables (31).

Toxic exposure, together with other health problems associated with poverty and inadequate housing, contributes to infant mortality rates in colonias and farm camps that are more than double the national average, as well as to a life expectancy of only 45 years for farmworkers, compared with 75 years for the general US population.

Industrial plants, especially maquilas (described below), are a significant source of hazardous wastes in the border region. Studies report neurotoxic and respiratory symptoms in workers exposed to solvents, dusts, and gases in the workplace (32). The responsibility for these risks sometimes lies with companies or managers for inadequate training, lack of safety equipment, and lack of emergency response planning; with government for lack of monitoring and enforcement; but also with workers who may not use or understand the use of available safety measures (32). Water sampling has revealed high levels of toxic substances, such as volatile organic compounds and heavy metals, in rivers and wells downstream of industrial facilities in Nogales and Mexicali. For example, a Mexicali study of 34 industrial plants found 117 chemicals in use, including solvents such as trichloroethylene and acetone, acids such as sulfuric acid, and heavy metals such as lead and nickel (33). Many of these chemicals were used only as auxiliaries (such as degreasers and cleansers) in production and created a lot of waste because they do not become part of the product but join the waste stream.

Threats to Natural Ecosystems

The ecological features of the border region vary dramatically, including chaparral-covered coastal plains; deserts of cactus, sagebush, and creosote; isolated mountain ranges with pine and oak forests; rugged canyonlands covered in yucca; rolling hills with grasses and mesquite; and fertile river delta estuaries. Major ecosystems of the border, such as the Sonoran and Chihuahuan Deserts, include many unique species adapted to dry conditions. Mountain ranges and riparian zones provide cooler, forested habitats important to both local species and migrants. The coastal zones at the eastern and western ends of the border include important estuaries and marine habitats.

The United States-Mexico borderlands are diverse in flora and fauna. The latitude of the region, coupled with its variety of biogeographic provinces, helps account for the diversity of this long narrow strip of land. Additionally, the varied topography of the region means that great variations in moisture, temperature, soil, and other environmental factors can exist within a few feet of each other. The United States-Mexico Border XXI Program reports that as many as 85 threatened or endangered species of plants and animals are found in the border area, as well as >450 rare or endemic species (34). It also notes that >700 neotropical migratory species (birds, mammals, and insects) use the borderland habitats during their annual migrations.

Many species and ecosystems had dramatic reductions in population numbers and area during this century. Included in the decreasing species are the larger mammals (such as the Mexican gray wolf and gray whale, pronghorn antelope, and bighorn sheep), and included in the shrinking ecosystems are the important habitats of forests and wetlands. The driving forces of land use change and habitat degradation have included the conversion of forests, grasslands, wetlands, and deserts to ranching, irrigated agriculture, and industrial and urban use; overexploitation

of game species and high-value wood; eradication of predators; competition for water between human and ecosystem uses; and change and variability in climate (35).

An ecosystem in great danger is the delta of the Colorado River, once a 3000-square-mile wetland that was the habitat for many migratory birds and unique marine species, such as the small porpoise called the vaquita and the totoaba fish (36). In the last 30 years, a reduction in the size and quality of flows of water and sediment from the river has shrunk the delta area by 50%, displaced species sensitive to salinity, and damaged the breeding areas for marine life. Flows have declined with increased upstream diversions and with frequent droughts, although the most severe damages occurred during the filling of the upstream reservoirs between 1945 and 1980 (37). Other estuaries at risk include that of the Tijuana River and the Rio Grande, including its adjacent coastal lagoons such as Laguna Madre. The discharge of wastewater and dredge spoil material into Laguna Madre is causing loss of sea grass and marine algae that are critical to the breeding of fish and invertebrates, as well as the loss of feeding areas for migratory waterfowl and the protected marine turtle (34).

The region's isolated mountain ranges, called "sky islands," are under pressure from urban development (for example, near Tucson), logging, mining, recreation, and grazing. These ecosystems protect species such as the wolf, jaguar, and songbirds, whose populations have fallen in the border region. The gray wolf was almost wiped out by aggressive predator control programs, hunting, trapping, and poisoning. The species has been extinct in the Southwest since the 1950s and in Mexico since 1980, and it was listed as endangered in 1976. The thick-billed parrot has disappeared from the US borderlands, and only small populations exist in Mexico.

The intersection of water and conservation issues with conflicts over environmental laws and economic growth can be clearly seen in the case of the San Pedro River, which flows north from Sonora into southeastern Arizona. The San Pedro is considered environmentally important because it is one of the last free-flowing rivers in the Southwest. It is an important route for migratory species, especially birds, and harbors several endangered species of reptiles, amphibians, and plants. However, the San Pedro Basin has a long tradition of water and land use for agriculture and communities. Among those that use the water are farmers irrigating alfalfa in the United States and corn in Mexico, livestock grazing throughout the basin, the Sonoran mining community of Cananea, and the rapidly growing city of Sierra Vista and the adjacent US Army base at Fort Huachuca, AZ. Hydrologists suggest that the pumping of the basin aquifer is reducing the flow of the river (38). The institution of the water rights doctrine known as "prior appropriation" protects the rights of agricultural users in the US section of the San Pedro, but this interpretation has recently been challenged through the establishment of a National Riparian Conservation Area, by the protection of species under the Endangered Species Act, and by the water rights claims of Indian tribes along the Gila, into which the San Pedro flows. Legal precedent suggests that federal and Indian rights may supersede others, and the conflicts

have catalyzed environmental and citizens' groups in the area as well as local government.

ENVIRONMENTAL HISTORY

The United States-Mexico border region has a long history of human impact on the environment, with archaeological evidence of prehistoric animal extinction, crop domestication, and irrigation development in southern Arizona up to 10,000 years ago. Ecosystems provided many resources that were valued by the indigenous peoples of what is now the border region, including game animals such as antelope and deer, cactus fruits and mesquite pods, fish, and wood for fuel and construction. Further transformations occurred once Europeans, led by Spanish conquistadors and priests, entered the region in the sixteenth century. These new settlers introduced Spanish traditions of livestock raising, wheat production, land tenure, and water development, as well as a market- and export-oriented economy and private ownership. During the colonial period, these actions brought overgrazing, deforestation, and urban and agricultural development to the border region. The earliest missionary settlements of the area were El Paso del Norte (in present-day Ciudad Juárez) in 1659, San Xavier del Bac (near Tucson) in 1700, and San Diego in 1769. Cattle spread across the landscape, and forests were cut for construction and fuel for mining and other developments, a process that formalized the early Spanish forays and settlements (39). Despite this environmental alteration, for centuries the border remained a relatively unpopulated region because of its semiarid climate, distance from centers of government, and insecure political conditions.The basis of the current boundary between the United States and Mexico was settled in the nineteenth century, when land was transferred from Mexico to the United States under the 1848 Treaty of Guadalupe Hidalgo and the 1853 Gadsden purchase, producing a boundary line that stretches almost directly eastward from San Diego to turn south along the Rio Grande at El Paso. The establishment of this boundary, along with the control of Indian (especially Apache) rebellion and cessation of hostilities between the United States and Mexico, encouraged settlement in the more-accessible areas of the border. Land settlement in the new US territories was promoted through a variety of "frontier" legislation, including the Homestead Act and the Desert Land Act, which gave land to settlers so long as they converted it to farmland, irrigated land, or ranchland.

Federal investment in the late nineteenth century by both the United States and Mexico in water development and railroads brought a boom to the border region, with the expansion of irrigated agriculture, ranching, and mining of gold, silver, and other metals. Towns such as Tombstone, AZ, and Cananea, Mexico, had mining-based population booms in the nineteenth century. The environmental legacy of mining and livestock in the nineteenth century included the deforestation of extensive regions around the mines and the erosion of arroyos in overgrazed areas. The traditions of cattle and mining and their associated environmental impacts remain important in many border states today (39).

By 1900, the US and Mexican border states had a combined population of ~6 million. The first 20 years of the century were prosperous for the US side of the border, with continued federal investment in infrastructure and rapid environmental transformation of land and water. But on the Mexican side, many people in the north felt disenfranchised from government in Mexico City, joining revolutionary movements for land and access to resources (40). The Mexican Revolution of 1910–1920 significantly disrupted economic development. However, many revolutionary leaders came from northern Mexico; in the aftermath of the Revolution, they directed investment in irrigation and roads to the north. Large irrigation districts were constructed in the northern states of Mexico by damming major rivers such as the Conchos and Yaqui and by developing groundwater resources. In the 1920s and 1930s, tourism, a new economic activity for the region, prospered in Mexican border cities as a result of Prohibition in the United States, and the associated urban development resulted in increased and unmanaged water use and waste production in growing cities such as Tijuana (41).

Throughout the early twentieth century, irrigation continued to drive the development of the border, especially for cotton, fruit, and vegetable production in California and along the Rio Grande in Texas. In both the United States and Mexico, the government supported water resources development for commercial crop production by using the waters of the Rio Grande and Colorado River in places such as the Imperial/Mexicali irrigation districts. Many agricultural users in the United States acquired "prior appropriation" rights for surface water and groundwater, and water use grew dramatically as crops were planted in the high-evaporation conditions of the area's hot desert climates. The doctrine of prior use/appropriation relied on the argument that a water source had been used "de tiempo immemorial" (since time immemorial). However, it did not guarantee the right to continued usage, but rather could help ensure favorable allocation of water in the absence of legal documentation (42). In Mexico, water rights have always rested with the federal government and were allocated in accordance with the balance of power between large commercial landholders and the communal ejido sector (land owned by the Mexican government to which communities have usufruct rights) (43). In both countries, these long-standing institutions for water and land use continue to play an important role in border issues.

The 1930s brought a further increase in federal investments through the New Deal in the United States and via President Lázaro Cárdenas' reformist economic policies in Mexico. North of the border, these investments included energy developments associated with major hydroelectric dams such as Boulder and Hoover on the Colorado River and the production of oil in California and Texas. The increasing development of water resources on the US portions of the Colorado River and Rio Grande raised concerns in Mexico and led to the signing of agreements between the two countries, ensuring flows of the Colorado River below Yuma (Colorado River Compact, 1922) and dividing the waters of the Rio Grande below El Paso (Rio Grande Compact, 1939). In Mexico, Cárdenas distributed land to peasant groups and created free-trade zones along the border. Import tariffs and

incentives designed to develop Mexican manufacturing capacity, and the demand during World War II for materials such as copper and steel spurred industrial development in northern Mexico, particularly in the border state of Nuevo León. In the United States, the border region became an important location for military bases, including the port of San Diego; major air bases in Tucson, AZ, and El Paso and Del Rio, TX; and a large Army base at Fort Huachuca in southeastern Arizona. Defense manufacturing and services grew in association with this military presence (44, 45).

Beginning in the 1950s, the introduction of hybrid seeds and agricultural chemicals into Mexico's irrigation districts in the so-called Green Revolution further increased agricultural production and food-processing industries in the border region and brought risks from agricultural chemical use to many rural areas (46). The agricultural, energy, and industrial developments of the past 60 years form the basis for the current structure of the border economy and associated environmental impacts.

Steady immigration to the border in both countries and relatively high human fertility in Mexico resulted in upward trends in the border population from the 1930s. The population of southern California began to increase dramatically with the attraction of employment in the armed forces, industry, and the service sector in cities such as Los Angeles and San Diego. Demand for Mexican labor in the United States, especially in irrigated agriculture, drew migrants to the border region, particularly after the formal Bracero guest farmworker program was introduced in 1942 to help fill labor shortages created by the war and attendant economic expansion. The social networks associated with the 4.5 million farmworkers who received permits to work under the Bracero program are a continuing link promoting undocumented migration to the United States and population growth in the border region (47, 48).

The forces of economic development, demographic change, institutional structures, and public policy have been important in transforming the United States-Mexico border environment. In the last 30 years, many of these forces have intensified in ways that have stressed the environment of this water-short region. At the same time, particularly over the past decade, increased public and political attention to the environment in both the United States and Mexico has yielded a variety of policies and institutions to manage environmental problems in the border region.

CONTEMPORARY DRIVING FORCES

The advent of the Border Industrialization Program in 1965 further transformed the region as Mexico and the United States introduced a program by which foreign-owned manufacturing plants could export back to the United States with reduced tariffs and trade barriers. These in-bond manufacturing and assembly plants are commonly called maquiladoras or maquilas, and, although the 1965 legislation restricted their location to within 12 miles from the border, in 1972 the zone

was expanded to all of Mexico except for the three major cities of Mexico City, Guadalajara, and Monterrey. The low cost of Mexican labor attracted plants to the border area initially for producing textiles and simple manufactured goods; however, these now include electronics, chemicals, and services such as coupon accounting. By 1990, there were >2500 maquilas employing a half-million people and producing $16 billion in foreign exchange—33% of Mexico's trade (Figure 2; see color insert). About 80% of the maquilas were located near the border, especially in Tijuana (605 plants) and Juárez (302 plants) (17, 44, 49). The unused byproducts from some maquilas, especially those using solvents and heavy metals, are a source of hazardous waste and air and water pollution (33). Maquilas also can demand significant quantities of water and have provided jobs that have drawn migrants to border cities in which there is insufficient infrastructure to provide safe water and sanitation to the new employees and their families. Even though many maquila workers earn salaries above the Mexican average ($1–$2/h), they still live in marginal urban settlements and lack public services (33).

Increased trade between the United States and Mexico has also driven economic development on the US side of the border, largely as a result of the intra-industry nature of much of this trade. The expansion of the assembly industry on the Mexican side of the border has led to the growth of complementary manufacturing activities, namely the production of parts and components for Mexican assembly plants in US border cities, effectively creating "binational production centers" along the border.

Agriculture has declined in economic significance in the border region as employment and profits in the industrial and service sectors have increased. In Mexico, agriculture and mining employed ~45% of the economically active in 1960, but only 15% in 1990. In the United States, the shift was from ~55% employed in primary sectors in 1960 to just 20% in 1990 (44). But despite this deemphasis, agriculture remains environmentally significant because it is a major water consumer, uses large areas of land, and is a non-point pollution source. Changes in agricultural subsidies and world demand have altered the composition of agriculture in the border region. The production of cotton, for example, has decreased with competition from Asia and the use of synthetics, and production of fruit and vegetables has increased with changes in US consumer demand for fresh produce and the development of processing plants in the border region. Another important shift has been an increase in the area devoted to forage, especially alfalfa, and to oilseeds, often at the expense of basic food grains such as maize and wheat (50).

In both industry and agriculture, technological changes have influenced environmental conditions along the border. For example, new mining techniques have reduced the environmental impact per unit of mineral extraction (although simultaneously, economic factors have made mining operations more extensive, thus affecting larger terrains), and water treatment and desalination technologies have permitted removal of biological and chemical contaminants in some communities (51). In agriculture, although the application of chemicals has increased in both countries over the last few decades, some of the more toxic substances such as DDT have been replaced by less hazardous pesticides and other inputs (52), although DDT is still used in Mexico. More efficient irrigation and energy technologies

have become available but are not always affordable (53). Technology also has created new environmental hazards in the border region, such as in the use of new processes in industry or the need to dispose of nuclear wastes, as exemplified by the Sierra Blanca waste repository in Texas (1).

The signing of NAFTA in 1993 consolidated these economic trends by removing many of the remaining barriers to free trade between the United States and Mexico. Supporters of NAFTA claimed that the pact would promote economic growth in the border region through industrial opportunities in both the United States and Mexico (54, 55). They also maintained that the agreement would yield a new agricultural equilibrium in which the United States would produce basic grains at low cost, and Mexico would have a comparative advantage in fruit and vegetable production. By contrast, opposition groups predicted that NAFTA would result in pollution havens as industry fled to Mexico's lower wages and laxly enforced environmental laws (56, 57). In many ways, NAFTA simply has formalized long-term trends in border industrialization and agricultural restructuring, perhaps accelerating some trends while reducing trade barriers.

The population of the border region continues to grow (Figure 3; see color insert), especially in the border twin cities, with the largest pairs—Tijuana-San Diego (1.8 million in 1990) and El Paso-Juárez (1.3 million in 1990)—exhibiting this trend most notably. The population growth rate in border regions of Mexico is ~3%/year and 2.7%/year on the US side (17). Although environmental problems on the border cannot be blamed solely on population growth, the combined impact of more people and increased per-capita consumption of resources has certainly contributed to resource demands and environmental pollution. For example, the rapid growth of the border cities has outstripped provision of basic services by the state. As a result, many border residents—in certain neighborhoods, a rising proportion—still remain without piped drinking water or sanitation (56). To feed the labor needs of the maquilas, many poorer residents of both Mexico and the United States have settled in colonias (unplanned communities) because they cannot afford to live elsewhere. These workers and their families are particularly subject to infrastructure-poor conditions (57). Most border residents aspire to own a car, and as these aspirations have been realized, gasoline consumption and air pollution have increased (58). Higher incomes also result in greater per-capita consumption of water and generation of household waste. For example, per-capita water consumption in Tijuana has doubled in the last decade to 385 liters/day and has reached 1350 liters/day in Reynosa. Average per-capita solid waste increased from 0.75 kg/day to 1 kg/day, and the overall waste production for the city of Tijuana almost doubled from 1990–1998 (27).

INSTITUTIONAL STRUCTURES AND SOCIAL MOVEMENTS

A variety of institutions—which, in the broadest sense, include formal laws and organizations as well as economic and political structures—influences the border environment. Some of these institutions, such as environmental laws and

post-NAFTA organizations like the Commission for Environmental Cooperation (CEC), arose from individual and collective social demands for environmental protection. In the remainder of this paper, we discuss the major institutional structures for managing the border environment, as well as the variety of nongovernmental organizations (NGOs) and groups that have pressured governments or are taking individual actions to protect health and ecosystems.

Public concern over environmental pollution during the 1960s prompted governments in both the United States and Mexico to pass environmental legislation and establish ministries in the early 1970s addressing environmental issues (59, 60). Although Mexico did establish institutions for the environment soon after the United States, the magnitude and speed of implementation, funding, and enforcement of environmental initiatives tended to be much stronger in the United States, and, whereas the major US institutions managing the border environment have remained relatively stable in structure (although with varying political support and budgets), the Mexican institutions have changed in name and structure several times before reaching the current characteristics of Secretaría de Medio Ambiente, Recursos Naturales y Pesca (SEMARNAP; the Ministry of Environment, Natural Resources, and Fisheries).

In the border region in the United States, as in the rest of the country, a large number of agencies and laws govern the environment. For example, pollution standards for air and water are enforced by EPA and a variety of state and municipal environmental agencies. To regulate these standards, the agencies make use of the Endangered Species Act and various regulations on the production, transport, and disposal of toxic and hazardous substances. Much of the western part of the border in the United States is public land, managed by the US Forest Service (Department of Agriculture) or the Bureau of Land Management and National Park Service (both in the Department of the Interior), or it is tribal land. In Mexico, the key agency is SEMARNAP, which is responsible for forest, land, and fisheries management; environmental compliance [through the Federal Attorney General for Environmental Protection (Procuraduría Federal de Protección al Ambiente; PROFEPA)]; and water (through the National Water Commission).

General Binational Agreements and Institutions

The earliest agreements between Mexico and the United States addressing aspects of the border environment concerned the area's most important resource, water. More particularly, it was the allocation of the waters of the region's two international rivers, the Rio Grande/Río Bravo and the Colorado, that drew the attention of the two nations. The instruments for managing these allocations and other associated issues—binational commissions and treaties—were handled within diplomatic channels. Accordingly, via the Convention of 1889, the two nations created the International Boundary Commission (IBC) and assigned it authority over the rivers, which partly defined the boundary (see Figure 1). Throughout this century, although the name of the commission has changed, this early arrangement

has continued (61). The evolution and evaluation of water agreements is further analyzed below.

Concerning environmental issues that are unrelated to the waters of the two rivers, the two countries had neither formal agreements nor jurisdictional entities for ~100 years after the establishment of the IBC. This lacuna is unremarkable in view of the general lack of attention to environmental matters preceding the 1970s. By the early 1980s, however, with increasing industrialization in the border region and with the population rising, new issues began to surface. Working primarily through the US Department of State and Mexico's corresponding foreign ministry (Secretaría de Relaciones Exteriores), but also for the first time with the environmental ministries, the two countries began discussing how they might cooperate to remediate environmental problems affecting the neighboring populations.

La Paz Agreement

In 1983, the presidents of Mexico and the United States, Miguel de la Madrid and Ronald Reagan, respectively, concluded the La Paz Agreement. This accord established technical working groups that, for the first time, would address such sensitive transboundary issues as water quality, air quality, natural resources, and solid and hazardous waste. Also for the first time, these groups reached beyond the diplomatic corps and included representatives of the environmental ministries and of the 10 state governments (62). With the addition of several working groups—there now are nine such task forces—the La Paz Agreement remains the basis of official United States-Mexico border environmental cooperation. Specific annexes of the La Paz agreement have established cooperation or controls dealing with wastewater treatment in San Diego-Tijuana (Annex I), hazardous spills (Annex II), hazardous waste shipment (Annex III), smelter emissions (Annex IV), and urban air pollution (Annex V).

Integrated Border Environmental Plan

Although the framework established by the 1983 accord was seen as a beginning, the two governments—with prodding from local citizens' groups and large NGOs—began seeking ways to expand the purview of the plan. In 1991, the US EPA and Mexico's then ministry of environmental affairs, the Secretaría de Desarollo Urbano y Ecología (SEDUE)[3] drafted a new plan for continuing the charge and extending the scope of the La Paz Agreement. The resulting document, titled the Integrated Border Environmental Plan (IBEP), was strongly criticized from the outset. IBEP had the objectives of strengthening enforcement of environmental laws, reducing pollution, increasing cooperation, and improving

[3]At the time of the 1983 La Paz Agreement, the Mexican ministry was known as the Ministry of Ecology and Urban Development (SEDUE); it was later reconstituted to include social development and renamed SEDESOL. Another reorganizing action created the present ministry, SEMARNAP.

understanding. IBEP was challenged for (*a*) some things it said (e.g. its repeated characterization of the border zone as arid wasteland); (*b*) many things it did not say (e.g. how nonurban environmental problems would be remediated, how data would be obtained and made available, how needed infrastructure would be paid for, and how the growing environmental burden should be shared equitably between the two countries); (*c*) its failure to acknowledge explicitly the impact of the then proposed free trade agreement; and (*d*) its virtually absent procedural and financial recommendations (62, 63). IBEP also had very little public input or participation.

Border XXI and NAFTA

In the end, IBEP's almost total absence of specificity and public participation doomed it, and, with new administrations in place in both the United States and Mexico, the two countries returned to the drawing board. By 1995, EPA and SEDUE's successor, SEMARNAP, had embarked on what was called the "U.S.-Mexico Border XXI Program," which was meant to correct the oversights of IBEP and guide cross-border environmental policy. In 1997, the two governments released the Border XXI Program's guiding document and set the program in motion (64). The new plan, the formal heir to the La Paz Agreement, defines nine areas of concern, each addressed through a binational technical working group: natural resources, water, air, hazardous and solid waste, contingency planning and emergency response, environmental information resources, pollution prevention, environmental health, and cooperative enforcement and compliance.

Border Environment Cooperation Commission and North American Development Bank

In the midst of the transition from IBEP to Border XXI, the United States and Mexico, along with Canada, negotiated and signed NAFTA. Partly to placate opposition from several powerful US environmental NGOs and partly out of a sincere desire to soften the potential impact on the border of increased commerce, Mexico and the United States agreed to charter three environmental institutions—two of which were to address exclusively the border environmental-infrastructure issues. The Border Environment Cooperation Commission (BECC) and its sibling, the North American Development Bank (NADB), were established by binational executive agreements between the United States and Mexico. The third, the Montréal-based Commission for Environmental Cooperation (CEC), was created by a specially negotiated Environmental Side Accord to NAFTA. CEC is charged with confronting environmental problems in the North American continent as a whole. The mission of CEC has been "...to address regional environmental concerns, help prevent potential trade and environmental conflicts, and promote effective enforcement of environmental law" (65).

What were the intents and missions of these new institutions? BECC and NADB together were expected to improve environmental infrastructure in the border region. BECC, headquartered in Ciudad Juárez, was to identify projects

in needy border communities and certify them as "environmentally sustainable." Then, the San Antonio-based NADB, working with BECC, was commissioned to assist in finding and obtaining funding for loans. What was dramatically different about these new institutions was that they were truly binational—operated by single boards with members from both countries, unlike previous binational arrangements in which each country had its own administrative structure.

In early 1995, BECC began considering how it would operate. Like any just launched organization, it developed policies, rules, and procedures. Almost immediately, too, BECC defined its agenda by selecting a programmatic emphasis. In view of the obvious impossibility of confronting and alleviating all the environmental problems in the border region, it decided to concentrate on water supply, water pollution, wastewater treatment, municipal solid waste, and "related matters."

As BECC established its modus operandi, it targeted what the directors saw as their chief tasks: identifying community infrastructure needs and, once identified, certifying projects considered appropriate and likely successful. Funding arrangements were to be separated from the certification procedure and left to NADB.

In the process of defining its approach, BECC incorporated and has retained a number of highly innovative design features that have characterized the commission: (*a*) binationality at all levels—policy making by its board, community advising, management, and staff; (*b*) preference for assisting disadvantaged communities; (*c*) openness and transparency; (*d*) bottom-up operation, with requirements for public participation at all levels; (*e*) avoidance of the regulatory or standard-driven approach—the norm for similar organizations elsewhere; and (*f*) emphasis on sustainability—economic and environmental (66). To ensure adherence to these principles, BECC has implemented a set of explicit criteria that projects must meet before obtaining the commission's certification.

In its 4.5 years of operation, BECC has elicited substantial interest from border communities. The commission has fielded >150 draft proposals and, by early 1999, had certified 27 of these (12 in Mexico and 15 in the United States). Once certified, the projects are forwarded to NADB, which then must arrange for financing. For the first 2 years, especially, the bank struggled to find sources for low-interest loans. The pace has quickened somewhat since then, and, by spring 1999, seven BECC-certified projects had NADB loans and/or grants approved and closed, with five of the projects under construction. Another seven projects had secured NADB financing, and five of those are being implemented (67).

For the most part, the paradigm put in place for improving environmental infrastructure in the United States-Mexico border region is a promising departure from the norm. BECC, in particular, has shown great promise in focusing on the needs and ambitions of border residents. The commission has done this by pursuing a goal of sustainable projects, by using ecological and social as well as engineering criteria to judge projects, and, through its emphasis on public participation, by beginning to promote a vision of social equity. Nonetheless, Mumme and other

observers caution that, if not properly guided, innovation and newness can become liabilities. Such analysts caution that it is essential for BECC to "finish" the policy-making process by simultaneously satisfying its varied publics, continuously adjusting its priorities, strengthening its institutional capacity, and, perhaps most importantly, meeting the high expectations through the success of its projects that the commission has set for itself, as well as the expectations of the affected communities (68, 69).

Commission for Environmental Cooperation

A third new institution spawned by NAFTA is CEC, an international organization whose members include Canada, Mexico, and the United States. CEC was created under the North American Agreement for Environmental Cooperation (NAAEC) to address regional environmental concerns, help prevent potential trade and environmental conflicts, and promote the effective enforcement of environmental law (65). The CEC has conducted or funded a number of studies on the state of the North American environment, on the relation between trade and environment, and on pollutant releases, registries, and ecoregions. However, it has generated most interest through its judgments on enforcement matters under Article 14 and 15 of the NAAEC. These articles allow any NGO or individual to file a submission claiming that one of the three countries is failing to enforce its environmental law. If the CEC determines that the submission meets certain criteria, a response is requested from the relevant country, and the CEC may then file a public factual record regarding the case. By the end of 1998, 20 submissions had been filed, several of which did not meet the criteria (including a requirement that the failure to enforce environmental regulations occurred after the implementation of NAFTA) or have been subsequently withdrawn. Others that met the criteria are awaiting responses from the relevant government or are still under initial review. Only the Cozumel Reef submission reached the stage of a factual record. It is too soon to fully evaluate the operation of the citizen submission process because of the small number that have met the criteria and achieved any level of resolution. The process has certainly generated publicity for some submissions, such as the case of construction of a cruise-ship terminal in Cozumel, Mexico, or the protection of the San Pedro River in the vicinity of Fort Huachuca, AZ, and has thus raised public awareness and government attention to certain issues. For example, the US Army has now commissioned its own study of the San Pedro and is adopting more serious water conservation. A submission regarding the pollution of the Río Magdalena in Sonora prompted the government to construct some oxygenation ponds.

Like BECC, the CEC has strong provisions for public participation, including a public advisory committee, public comments on submissions and publications, and the opportunity for the public to file submissions themselves. The CEC has been subject to some political pressures and wavering political support; to criticisms regarding bureaucracy, the narrowness of the criteria for the citizen submissions,

delays, and inadequate public participation; and to considerable uncertainty about its funding and mandates (70).

Other Institutional Changes

Other institutional changes have been responses of decision makers and leaders to broader economic and political trends. In Mexico, the adoption of a neoliberal economic agenda by politicians and their economic advisors resulted in major land reforms and the privatization of state-owned industries and water utilities. The environmental implications of these changes are not yet clear. It may be that private ownership will promote more efficient use of water and materials or that the private sector will be able to ignore environmental regulation by weak state and local governments. In 1992, the Mexican government announced a change in Article 27 of the constitution, allowing land in the collective ejido system to be sold, rented, or used as collateral for the first time since the revolution (71). Some authors suggest that the Article 27 reforms are likely to result in increased sales of timber and in the agricultural intensification and more chemical use on better-quality land (72). Pressures from multilateral development banks, as well as the debt and economic crises, led to the withdrawal of state subsidies for agriculture and welfare and to reduced support for government environmental management activities. Environmental management in Mexico remains comparatively underfunded and lacks professionals and data ($0.24 per capita for enforcement and only ~500 professionals) (27). In the United States, the property rights movement to transfer public lands to state or private ownership and reduce statutory controls on the use of private property somewhat curtailed the impact of federal legislation and land use protection, and it has created serious conflicts between landowners and environmental-management agencies (59). In Mexico, public pressures for free and fair elections have transformed that nation's political landscape in the last decade from centralized domination by one party to more decentralized government with significant opposition control of states and municipalities (73).

Border Environmental Nongovernmental Organizations

The border strip straddling the frontier between the United States and Mexico separates countries having vastly disparate economies and correspondingly different levels of infrastructure. Yet as border zones, the regions in both countries share what is a common characteristic of such peripheral areas: they are far from their national capitals and the political patronage, decision-making structures, and financial-support levers whose loci are at those centers. As a result, the problems of the border have often been assigned low priority (56). One response to this neglect has been the development of social movements to demand improved living conditions and environmental protection and the formation of diverse NGOs.

Although many regions of the US border states (such as the lower Rio Grande and southern New Mexico) are less well-to-do than the country as a whole, they still surpass Mexican communities in per-capita incomes; prevalence and

efficiency of public works; number of trained personnel; and development of public, quasipublic, and private institutions. NGOs have had a longer and more active tradition north of the border. National groups such as the Sierra Club, National Wildlife Federation, Natural Resources Defense Council, and Environmental Defense Fund have operated effectively and influentially on the domestic front for several decades. Over the past 20 years, in many instances, local chapters of these and similar organizations also have found niches, developed persuasive agendas, and played instrumental roles in helping shape local and regional policies. As some of these chapters developed more focused action plans, splinter groups arose (74, 75).

At the same time, a new phenomenon began to surface: entirely distinct, community-based NGOs began to form—many of these coalescing around purely local, single issues. With proceeds from membership dues, donations from sympathetic residents, and skillful grantsmanship, these organizations were able to finance vigorous and well-targeted programs. In the United States, where higher income levels, more leisure time, and a greater tradition of social activism permitted such engagement, these grassroots NGOs began to exert influence alongside the now-traditional national groups and their local branches (20). By and large, the missions of these organizations are similar and include environmental and economic justice, environmental health, pollution prevention and ecosystem protection, empowerment and activism, and accountability and right-to-know (75). Arizona's Border Ecology Project, California's Environmental Health Coalition, New Mexico's Interhemispheric Resource Center, and the Texas Center for Policy Studies—all dating at least to the early 1980s—have been among the most stable and effective US-based organizations of this type.

Applying techniques of social mobilization honed during the late 1960s, these groups have combined a populist approach with quiet but shrewd political action. They have stirred public opinion through highly visible campaigns (e.g. the Border Ecology Project-led antismelter movement of the mid-1980s in southeastern Arizona), community-organizing (e.g. the Environmental Health Coalition's 5-year effort, culminating with legislation, in 1997, to ban the use of the toxic pesticide, methyl bromide, in areas adjacent to poor Latino communities), and information dissemination (e.g. through widely distributed publications, such as the Interhemispheric Resource Center's *Borderlines*). Simultaneously, these groups have influenced decision making via well-targeted, carefully crafted, behind-the-scenes efforts (e.g. the Texas Center for Policy Studies's late-1992, pre-NAFTA tactic of drafting and then circulating a white paper proposing to create a binational, transborder environmental commission—a document whose traces are clearly evident in the subsequent design of BECC). As part of the success and effectiveness of these NGOs, the Ford Foundation, Charles Stewart Mott Foundation, and other large US-based philanthropic organizations have provided substantial support for the work of these and similar groups (1).

In Mexico, the situation has been quite different. There, since the revolution of the 1910s, the chief manifestations of spontaneous populism have been

the social movements of the urban and rural poor. Typically these organized efforts have addressed standard-of-living issues, land tenure rights, and wages and labor conditions. More recently, some not-for-profit civic organizations have begun championing such contemporary causes as democratization and political reform; human, indigenous, and women's rights; and environmental protection (76, 77).

Throughout Mexico, the ability of unofficial groups to function is severely constrained by the federal government, which does not accord NGOs legal standing. However, certain less radical groups received unofficial sanction from the government, following the corporatist tradition of Mexican politics, and received access to the government-controlled media and some financial support so long as they protested only within certain permitted limits.

In Mexico, groups whose chief concern is the environment emerged principally in the country's interior. They included Pronatura (focusing on nature conservation), the Grupo de Cien (a group of writers and artists that publicized environmental causes), and the Movimiento Ecológico Mexicano (2). Other successful organizations in southern and central Mexico were able to ally themselves with proponents of more traditional grassroots causes and with NGOs that advocate economic development (78). Additional limitations on Mexican NGOs include a lack of funding from government, membership, or private foundations; a tendency toward elite membership because only the better-off have the time or resources to participate; competition between groups for scarce resources; and a general lack of information. In addition, although Mexican NGOs have nonprofit status, they must pay taxes and cannot give tax relief to donors or members (79, 80).

In the six Mexican border states, the effectiveness of environmental groups has been difficult to gauge. In the western part of the border region, according to Zabin (76), such groups have formed fewer partnerships with social-action groups than have their counterparts elsewhere in Mexico. As a result, they have had less visibility and less success. But the situation appears to be changing. Since 1990, the number of environmental NGOs in Mexico clearly has risen, and, spurred by post-NAFTA events, the trend is continuing. The advent of BECC and, in particular, its promotion of public participation (see below) have helped spur the creation of new grassroots organizations and the maturation of existing ones. In Nogales, Sonora, for example, the Acuaférico project certification process (discussed below, in the section on urban water issues) has mobilized organized citizen response both for and against the project (81). Even before this, the Nogales, Sonora citizenry was aroused by a series of crises concerning water quality (19, 23).

To prompt greater levels of participation by Mexican environmental NGOs and community-based organizations (CBOs), the Ford Foundation and the Charles Stewart Mott Foundation have supported an annual series of meetings on the border environment (Encuentro Anual Sobre El Ambiente Fronterizo). These meetings are tailored to the needs of NGOs and CBOs and are aimed at capacity building. The first two meetings, in 1998 and 1999, drew a strong response from Mexican groups. In 1998, >400 persons from the two countries participated, and in 1999, attendance

swelled to >450; most notable, however, was that attendance was almost equally divided between persons from the United States and from Mexico. About 65 Mexican border NGOs and CBOs were represented at each meeting, confirming the growth and vigor of this sector and suggesting greater future influence in Mexico's environmental policy making process (1). The diversity and number of environmental groups are also evident in several directories of NGOs and other organizations working on the United States-Mexico border (82–86).

INSTITUTIONAL STRUCTURES AND COLLECTIVE RESPONSES TO WATER ISSUES

The traditional institution for managing transboundary water resources is the International Boundary and Water Commission (IBWC). For more than a century, Mexico and the United States have dealt with transboundary resource issues through a rather unique binational institution. The IBWC, whose origins began with the signing of the Convention of 1889 between the two nations, was created to resolve differences that had arisen or might arise related to meander changes of the Rio Grande/Río Bravo and the Colorado Rivers, both of which form segments of the international boundary (61, 87).

Although the 1889 convention made no mention of water allocation from the rivers, problems had emerged some 20 years earlier over just such an issue. Mexico had complained that water was being used for irrigation in New Mexico to the detriment of downstream farmers in the Valley of Juárez. Discussions between Mexico and the United States during the 1890s eventually led to the Water Treaty of 1906, the main elements of which were that the United States would build a dam upstream of the Valley of Juárez for water storage and flood control and that the United States would deliver 60,000 acre feet of water annually to Mexico at the Acequía Madre, located a few miles downstream from El Paso-Ciudad Juárez, which would be used for irrigation in Mexico. However, in the event of extraordinary drought or disruption of the system, both countries would receive reduced amounts of water, diminished in the same relative amount.

During the 1920s, both countries established an international commission to examine overall strategies for more equitable use and allocation of water in the Rio Grande/Río Bravo, specifically focusing on the lower watershed below Fort Quitman, as well as on water in the Colorado and Tijuana Rivers. The tasks of this International Water Commission were merged in the early 1930s with that of the preexisting IBC. In 1944, the two countries signed another water treaty that renamed the IBC as the IBWC (International Boundary and Water Commission),[4]

[4]The IBWC is the name of the US section of the commission. The Mexican section, which is distinct, is the Comisión Internacional de Limites y Aguas (CILA); it is situated within Mexico's Ministry of Foreign Affairs. For simplicity, we use the term IBWC to refer to both the US and Mexican components.

reflecting its expanded responsibilities, which included handling allocations for water from the aforementioned rivers, as specified under the new treaty; obtaining and keeping records for stream flow, water quality, and precipitation; and operating and maintaining dams for water storage and flood control that were to be built by the United States on the main channel of the Rio Grande, specifically the Falcon Dam (1953), the Amistad Dam at Ciudad Acuña-Del Rio (1969), and the Anzalduas Diversion Dam (1960).

Because of the physical nature of the border region (low rainfall and water scarcity), the responsibility of the IBWC has enlarged to include water resources management. Subsequently, through a number of treaties between the two nations, the most recent ratified in 1944, the IBWC has expanded its duties to include responsibility for allocating water from the Rio Grande, Colorado River, and other minor rivers and associated tributaries, as specified in water allocation treaties. These actions have included dam construction and operation to provide for water storage, flood control, and hydroelectric power; maintaining the river and land boundaries; and constructing and operating sanitation and sewage-waste–treatment facilities in certain areas along the border. In addition, as circumstances have dictated, the IBWC also has assumed responsibility for overseeing groundwater use in the Colorado River Basin near the Arizona-California-Sonora border area, monitoring the salinity levels of the Colorado River as it enters Mexico, and adjusting alternations in the boundary caused by river meandering.

Although the IBWC has operated efficiently and effectively within the focus areas just described, many observers have charged that it has failed to respond to such major border region resource problems as air pollution, water pollution, overpumping of groundwater, hazardous-waste disposal and transport, and threats to the natural biological resources of the area. Critics also suggest that the IBWC has not been receptive to public input in its decision-making processes and that it does not make accessible to the public information it has on border resources. The response to these latter criticisms is that, because of the unique nature of the IBWC, which often involves delicate negotiations between two nations, the IBWC has maintained a certain distance from what might become politicization of its mission. The commission also has been mindful of its authority and responsibility vis-à-vis state and national agencies that have missions related to environmental protection, and it has been reluctant to overstep the boundary of its authority. Still, because of the need for environmental impact statements under the National Environmental Protection Act of 1970, the IBWC does have to allow more public input and oversight than it used to. Also, under a 1983 agreement between Mexico and the United States, EPA and its Mexican counterpart, SEMARNAP, are the designated lead agencies concerning environmental matters along the border. Thus, although Mexico and the United States have had an effective institutional mechanism in the IBWC to manage certain border resources (i.e. surface water in the major border rivers), other agencies have had to enter into the arena of border environmental management as it relates to what the IBWC perceives as being beyond its mission and political capabilities (62).

Responses to Urban Water Issues

In Texas and New Mexico, the colonia problem can be traced to the evolution of land settlement and the reluctance of rural counties—often just beyond the limits of neighboring cities—to deal with the emergence of these settlements. As a result, colonias sprout on unplatted lands and remain for years, if not decades, without basic services. Although the states recognize the severity of the problem and, in Texas, agencies have allocated remedial funds, actual improvements have been slow and have had little impact on the overall situation, fostering anxiety in the communities (88).

In response to the seeming inability of the public sector to alleviate the lack of water supply and waste-treatment infrastructure, an NGO, the Santa Fe-based WaterWorks Program, has stepped in to try to achieve short-term gains. This innovative, pioneering effort, in operation since 1996, has been funded by the Pew Charitable Trusts, which views the project's community-based, self-help approach as a potential model for the area. In its short lifetime, WaterWorks has operated in selected colonias in New Mexico and Texas, working with Latino community leaders called "spark plugs" and highly trained and committed staffers who, using local labor and leveraged public funds, encourage and teach residents to construct their own water and sanitation systems. This project remains experimental, and its intent is to persuade public agencies to adopt a similar approach to accelerate progress while reducing costs.

In Ambos Nogales, the water supply and quality problems prompted a coalition of governmental and quasigovernmental organizations on the Mexican side to seek approval from BECC for a large water development project. A technical proposal to establish a water supply and distribution system, termed the "Acuaférico," was submitted in mid-1995. In January 1996, at a heated and colorful public meeting attended by perhaps 500 residents, the BECC commissioners certified the (US)$39 million project. The $21 million first phase of the Acuaférico aims to rehabilitate the existing waterpipes, which currently leak at a 40% rate, construct 33 km of distribution lines, improve the efficiency of pumping, construct elevated water tanks, and substitute extraction wells (89).

The NADB has acted as investment banker for the state government of Sonora and is a potential direct lender, but the funding process has been slow and difficult to arrange. As of November 1998, nearly 3 years after the project's certification by BECC, a $9 million loan for Phase I of the project was being negotiated between the bank and the private contractor, who will contribute 10% of the cost of the project as equity. Through its Institutional Development Cooperation Program, the bank also is providing assistance to the local water utility for a waterline survey and information system. In spite of the difficulty of securing NADB-facilitated funds, the project has moved ahead and is under construction, thanks to direct financial support from the Mexican government. To complement the Acuaférico, in view of Nogales' serious requirement for additional solid-waste treatment capacity, NADB authorized additional assistance in August 1998, for a needs assessment (67, 90).

The Nogales experience highlights both the promise of the post-NAFTA BECC/NADB process and the institutional impediments to its rapid implementation. Because of the progressive criteria of the BECC, the Acuaférico project has been designed to meet the commission's requirements for environmental sustainability, public participation and transparency, and financial self-sufficiency. But for projects undertaken in Mexico, this last requirement often proves problematic because municipios (city governments) lack taxation authority, and local resources are nearly always inadequate to ensure repayment of loans. As a result, some local citizens, particularly those on the left politically, have been concerned that the weight of repayment would fall unduly on the shoulders of those least able to afford such costs—maquiladora workers, colonia dwellers, and other poor residents. Additionally, the very provisions of the BECC certification procedure that stand out as innovative and environment-sensitive are the same ones that can constrain the ability of NADB to secure low-interest financing (91).

Responses to Air Pollution

Both the United States and Mexico regulate air pollution through health-based ambient standards. Mexico's standards match those of the United States for particulates and are slightly stricter for sulfur dioxide and ozone, but many Mexican communities lack monitoring equipment and the professionals or the commitment to enforce standards. The countries first agreed to cooperate in managing transboundary air pollution under the 1983 La Paz Agreement.

An example of innovative transboundary environmental cooperation has been the Paso del Norte Air Quality Task Force. This task force is a binational group formed in 1993 with governmental, nongovernmental, industrial, and academic representatives, in addition to concerned citizens. The goals of the group are to create a locally based entity in charge of the region's air quality. The group works within the framework of each country but without having to depend on decisions made from desks hundreds of miles away in Washington and Mexico City. The task force has been able to persuade both federal governments to recognize the existence of a common air basin in which Ciudad Juárez, El Paso, and southern New Mexico's Doña Ana County are located. With the official recognition of the Paso del Norte Air Basin, in May 7, 1996, also came the creation of a binational advisory committee. The Paso del Norte Joint Advisory Committee (JAC) has been established primarily to provide recommendations to the Air Working Group of the Border XXI Program (also of the La Paz Agreement). The JAC has 20 members equally divided by country and government and nongovernmental representatives. The federal representatives include one from the United States and three from Mexico (showing the still strong influence of the Mexican federal government in local border issues). The task force is seeking to use the JAC as a mechanism to influence policies to be implemented in the region.

The main focus of the task force has been to seek ways in which institutions and individuals on both sides of the border can cooperate and work together to

improve the basin's air quality. Such a focus has allowed its members to work on specific issues. For example, the task force's brick maker project has been able to raise awareness about the problems of burning solid fuels, as well as to develop alternatives to make its operation more efficient and less polluting. Some NGOs in the task force have been strongly supporting and promoting, with the help of government agencies, the concept of transboundary-emission credit trading as a way to reduce overall air pollution in the basin. A company in the United States, for example, could receive credit for reducing pollution if it helps to reduce emissions in Mexico. One case has already occurred and another pilot case is planned to prove that such a policy is possible and workable. Other projects have involved direct support to the air-quality inspection and maintenance programs in the region, together with training about how to reduce air emissions in their operations to local mechanics and paint shops on both sides of the border. Finally, members of the task force have championed a project to establish a high-volume, dedicated communication line to cross the border northbound, as well as to develop a basinwide Geographic Information System of the most relevant point sources of air pollution. Over 2500 points have been identified, and the system is being used by planning offices on both sides of the border, as well as in universities.

Responses to Toxics and Hazardous Waste

Environmental and labor groups have continued to campaign to reduce pesticide risks, especially to migrant farmworkers exposed to agricultural chemicals both in the fields where they work and through inadequate water supplies in colonias and other settlements (31). Although the binational La Paz Agreement states that waste associated with chemicals imported from the United States into Mexico must be reexported, it is estimated that <25% is, in fact, returned to the United States, with >65% of maquila waste unaccounted for in either the United States or Mexico (92). Because only two companies in northern Mexico are authorized to treat hazardous waste and treatment remains costly, many wastes are illegally discharged into waterways or onto land.

The now defunct IBEP promoted a hazardous-waste–tracking system for transborder shipments, and, although this system is functioning and has been used to enforce some rules, there are still binational disagreements about the data quality and sporadic input of information from Mexico (33, 93). The US and Mexican governments have also initiated and supported recycling, and they have increased monitoring and enforcement of wastes and pollution through the EPA and PROFEPA, the enforcement division of Mexico's environment ministry.

A number of environmental and public-health groups (e.g. Border Ecology Project, Arizona Toxics, La Red Fronteriza de Salud y Ambiente) have pressured both federal governments for toxic cleanup and especially for public right-to-know about the prevalence, use, and disposal of toxics in the border region. NGOs also have initiated informal monitoring of water quality because of the lack of public information about toxics. Mexico has adopted a pollutant-registry system to

register and track pollutants, but information is not yet widely or publicly available. Further, local groups have opposed the location of new hazardous disposal sites on both sides of the border because of inadequate safety precautions and lack of public participation or impact-assessment procedures. For example, there has been strong public opposition to sites near Hermosillo, Sonora, and near General Cepeda in Coahuila, although local governments had secretly negotiated to approve the locations (93). Environmental groups on both sides of the border united in 1998 to oppose proposals for a low-level radioactive waste disposal site at Sierra Blanca, on the US side of the border (1).

Although government policy and public pressures have heightened awareness of the amount, nature, and management of toxic and hazardous waste in the United States-Mexico border region, the state and social movements have a limited ability to control pollution in the face of rapid industrial and agricultural expansion. The solutions to toxic-pollution reduction reside, to a large extent, in the willingness of industry to adopt less polluting technologies and improve waste management. Remediation also requires a framework of government regulation or incentives, consumer and public action, and the economic efficiencies of recycling and waste reduction.

Responses to Conservation of Natural Ecosystems

The broad biodiversity in the border area, combined with increasing pressures on the region, provides the impetus for a great deal of conservation work by public agencies and private organizations. Efforts take either an area-specific approach (e.g. concentrated on the Sonoran Desert or the San Pedro River) or a species-specific approach (e.g. addressing the fate of the Mexican gray wolf or resident bat communities). A number of alliances have formed, uniting the energies of different groups with similar concerns from both sides of the border.

Both the United States and Mexico established institutions for the management of natural ecosystems early in the twentieth century. These include the US Forest Service (1905), National Park Service (1916), and Fish and Wildlife Service (1936), and the Mexican forestry law (1926) and Department of Forestry, Fish and Game (1935). Border cooperation began with early concerns over migratory species (including birds and marine mammals), a 1935 meeting of an International Parks Commission to discuss protected areas along the border, and the 1936 signing of a treaty on the Protection of Migratory Birds and Game Mammals (60). These government institutions were paralleled by the emergence of public-interest organizations such as the National Parks and Conservation Association, Audubon, and National Wildlife Association in the United States, and the Committee for the Protection of Wild Birds and the Mexican Forest Society in Mexico, which worked for the conservation and protection of certain species. In 1984, the US Fish and Wildlife Service signed an agreement to cooperate on wildlife conservation with the Mexican environmental agency; in 1988, the two nations signed a cooperative agreement on the management and protection of national parks and other protected

sites (34). Although the United States signed the Convention on International Trade in Endangered Species in 1971, Mexico was a center of trafficking and did not sign until 1991.

Pressure, including coordinated campaigns, from environmental groups in both countries has been associated with government programs to recover several species. For example, the Mexican Gray Wolf Recovery Project, approved by the US Fish and Wildlife Service and the Mexican Dirección General de la Fauna Silvestre in 1982, included programs of captive breeding and restoration of wild populations. In March 1998, the US Fish and Wildlife Service released three family groups, totaling 11 wolves, all fitted with radio transmitters, from acclimation pens into the Apache National Forest of eastern Arizona, an area chosen for its large prey base and drought resilience. The goal is to reestablish a wild population of at least 100 wolves over an area of 5000 square miles, with families of wolves being released over the next 5 years until population growth can be sustained naturally. Since release, however, 7 of the original 11 wolves have died or been killed and the remaining 4 have been recaptured, necessitating the introduction of a new cohort. The conservation of gray whales has been more successful because of national and international bans on whale hunting and because of protection of breeding grounds in Baja California. The population has recovered to <20,000 (94). A proposed saltworks north of the San Ignacio Lagoon in Baja California threatened the whale nursery but has been strongly opposed by coalitions of US and Mexican environmental groups, including the Natural Resources Defense Council, World Wildlife Fund, Grupo de Cien, Pronatura, and ProEsteros.

Innovative binational groups have emerged in support of specific ecosystems. For example, the International Sonoran Desert Alliance aims to preserve and protect land in the western Sonoran Desert. The alliance comprises residents, business leaders, federal and state administrators of natural resources, civic organizations, and scientists from Mexico, the United States, and the Tohono O'odham Nation. The Sky Island Alliance is dedicated to the preservation and restoration of native and biological diversity in the mountain ranges of the southwestern United States and northwestern Mexico. The Rio Grande Alliance is a crossborder union of environmental interests addressing the state of the Rio Grande/Río Bravo. It exists as an international forum to support collaboration among the diverse groups of the Rio Grande Basin that are concerned with the protection, improvement, and conservation of natural resources and human health, as well as to improve cooperation and coordination of environmental activities in the Rio Grande Basin. Another group, the Rio Grande/Río Bravo Basin Coalition, aims to facilitate local communities in restoring and sustaining the environment, economies, and social well-being of the river basin (84, 86).

These binational conservation groups face many challenges, including the difficulties of working through several levels of government in both countries, the asymmetries in resources between the US and Mexican sides of the border, and risks that smaller NGOs or Mexican or indigenous partners will feel dominated by US-based environmentalists or large conservation organizations.

The San Pedro River provides an example of a new NAFTA environmental institution acting to conserve ecosystems. In 1996, an environmental group, the Southwest Center for Biodiversity, filed a claim with CEC suggesting that the United States had failed to enforce its environmental laws in permitting the expansion of Fort Huachuca without an environmental impact assessment. The Southwest Center withdrew its claim, and the CEC agreed to conduct a study of the San Pedro situation. A trinational review panel concluded that development was threatening the riparian area and proposed a variety of solutions, including the purchase of agricultural water rights and the reintroduction of the beaver to increase wetland area (38).

CONCLUSIONS

The long border strip separating the United States from Mexico is a region like no other in either of the two countries. On the one hand, the zone features a high degree of cross-national cultural and commercial integration and a tradition of transboundary ties. But on the other hand, the international boundary separates nations having vastly disparate political systems and levels of economic strength, with both capitals distant from the region. Before the 1980s, the most frequently addressed issues affecting border residents were legal labor exchanges and undocumented or illegal immigration, illicit drug traffic, and, in some locales, large-scale tourism. But about two decades ago, the region's environment and natural resources began to draw attention. Often brought to the table by ad hoc, locally based environmental groups and citizens' coalitions, these environmental issues, initially focused on perceived dangers to human health in urban communities on both sides of the border from air and water pollution; later, water and conservation issues became concerns.

In both the United States and Mexico, the state responded to public concern through the establishment of national institutions for environmental management, including government departments and legislation, and through binational diplomacy that resulted in several agreements and the establishment of innovative binational organizations, such as the IBWC. Before long, this discussion began to address the aging and inadequate water-delivery and removal infrastructure, and the depletion of resources, especially water. Eventually environmental concerns expanded to include problems affecting nonurban areas (e.g. the deleterious effects of irrigated farming and mining, loss of woodlands and riparian habitat, poor land-use planning, and destruction of coastal-zone ecosystems). In all the above cases and in those of many border-environmental issues, social equity and justice are important considerations. The border is generally an area of low incomes and poorly developed public-works systems, and unequal distribution of services is a continuing problem.

During this time, the border area's economy and population profile was being transformed by the two nations' manufacturing and trade policies and by overall

growth and restructuring of the global economy. Through improved incentives, Mexico and the United States promoted the growth of a border industrial base. This phenomenon brought with it migration from Mexico's interior to meet labor demands in maquiladoras and other border economic enterprises. It also engendered a transformation of the region's demographic and consumption patterns, and it stressed the capacity of border communities to accommodate these changes. In 1994, these forces were intensified with the implementation of NAFTA. As we have discussed, NAFTA galvanized social movements and binational grassroots collaboration in the border region, and it led to the creation of several new binational institutions—such as BECC, NADB, and CEC—with strong emphases on public participation.

The relationships between society and environment in the border region are strongly influenced by the constraints of the physical environment, especially water, and by the rapid restructuring of the economy, especially the growth of services and cities in the United States and industrial manufacturing and export agriculture in Mexico. Water clearly is the single most critical natural resource of this predominantly dry region. Availability of water for household use, industrial development, agriculture, mining, recreation, and habitat vitality is becoming more scarce as demands exceed supplies of fully allocated surface waters and as aquifers are being rapidly depleted. Such driving forces of the environment and the global economy are mediated by a variety of institutions that have been established to manage and reconcile the use of resources and the impacts of growth in the region. These institutions, in turn, are transformed by the actions and opinions of individual border residents expressed through NGOs and through public inputs to decisions and the media.

It is the interaction, in a binational context, between local ecological conditions and global economic restructuring through trade agreements such as NAFTA, as well as between institutional developments and social movements, that makes the United States-Mexico border region such a compelling place in which to study environmental issues and public policy. In this paper, we have sketched some of the historical and current dimensions of issues and institutions in the border region, with a particular focus on some of the developments associated with NAFTA.

We believe that, although NAFTA challenged local capacity and, in the view of critics, threatened a fragile environment, it has created opportunities for new organizations and institutions with missions to improve conditions for people and ecosystems. For example, the BECC has put in place innovative institutional designs, including a strong element of democratization of environmental decision making. This has been complemented and challenged by a rise in the mobilization of certain segments of the population and a spurt in nongovernmental activity and activism. NGOs and CBOs are playing an increasingly important role in helping to shape the environmental agenda for the border region. The rise in number and in influence of NGOs on the Mexican side is particularly noteworthy in view of the political and economic conditions in that country.

Since free trade was implemented in 1994, Mexico has experienced several other important changes and events that, to some extent, overwhelm the direct effects of NAFTA in northern Mexico. For example, economic crises and associated declines in the value of the peso have made Mexican labor even cheaper to foreign companies and have been a key cause of continued maquila development. On the other hand, internal political and economic problems have limited environmental enforcement and the development of urban infrastructure, and these have led some rural dwellers to overexploit resources to survive. Sustained drought has caused agricultural losses, ecosystem damage, and water conflicts across northern Mexico.

Political transformation in Mexico also brings challenges with changes in land and water law, the end of one-party rule and the emergence of multiparty legislatures, and the decentralization of responsibilities—including some environmental management activities—to state and municipal governments. These new configurations are still being negotiated within Mexico, and their implications for border cooperation are as yet unclear.

ACKNOWLEDGMENTS

The authors are grateful for the invaluable research assistance provided by Rachael Ingall, a graduate research assistant at the Udall Center for Studies in Public Policy at The University of Arizona. Patrick Barabé, a graduate assistant at the Center for Applied Spatial Analysis at The University of Arizona, prepared the map of the border region. The present article could not have been written without support for the Udall Center and Latin American Area Center by the Ford Foundation and project funding from the Charles Stewart Mott Foundation and the Pew Charitable Trusts. We also acknowledge helpful comments from two anonymous reviewers, as well as from Margaret Wilder and Wendy Laird-Benner.

LITERATURE CITED

1. Encuentro Fronterizo. 1998. *Report of 1998 Meeting on the Border Environment.* http://w3.arizona.edu/~laac/bordconf.htm
2. Simon J. 1997. *Endangered Mexico: An Environment on the Edge.* San Francisco: Sierra Club. 275 pp.
3. Barry T. 1994. *The Challenge of Cross Border Environmentalism: The U.S.–Mexico Case.* Albuquerque, NM: Interhemispheric Resour. Cent.
4. INEGI. 1995. *Censo Agrícola, Ganadero y Ejidal 1990–91.* (CD-ROM). Mexico City: Inst. Nacional de Estadística, Geografía y Informacíon
5. Liverman DM. 1999. Vulnerability and Adaptation to Drought in Mexico. *Nat. Resour. J.* 39(1):99–115
6. Liverman D, Magana V, Conde C. 1998. *Climate Variability and Transboundary Freshwater Resources in North America: US–Mexico Border Case Study.* Montréal: Comm. Environ. Coop.
7. Powell Consortium. 1995. *Severe Sustained Drought: Managing the Colorado River*

System in Times of Shortage. Tucson: Ariz. Water Resour. Res. Cent. 165 pp.
8. Liverman DM, O'Brien KL. 1991. Global warming and climate change in Mexico. *Glob. Environ. Change* 1(4):351–64
9. Revelle RR, Waggoner PE. 1983. Effects of a carbon dioxide induced climatic change on water supplies in the western United States. In *Changing Climate: Report, CDA Comm.*, pp. 111–20. Washington, DC: Natl. Acad. Sci.
10. Nash LL, Gleick PH. 1991. Sensitivity of streamflow in the Colorado Basin to climatic changes. *J. Hydrol.* 125(3–4):221–41
11. Nash LL, Gleick PH. 1993. *The Colorado River Basin and Climatic Change: the Sensitivity of Streamflow and Water Supply to Variations in Temperature and Precipitation.* Washington, DC: US Environ. Prot. Agency Off. Policy Plan. Eval.
12. Schmandt J, Ward G. 1991. *Texas and Global Warming: Water Supply and Demand in Four Hydrological Regions.* Austin: LBJ Sch. Public Aff., Univ. Tex. Press
13. North GR, Schmandt J, Clarkson J, eds. 1995. *The Impact of Global Warming on Texas: A Report of the Task Force on Climate Change in Texas.* Austin, TX: Univ. Tex. Press
14. Mumme SP. 1988. *Apportioning Groundwater Beneath the US–Mexican Border: Obstacles and Alternatives.* La Jolla, CA: UCSD Cent. US–Mex. Stud., Univ. Calif. Press
15. Utton AE. 1989. The importance of United States–Mexico water relations. In *Water and the Future of the Southwest,* ed. ZA Smith, pp. 71–88. Albuquerque: Univ. NM Press
16. El Paso Water Utilities Public Service Board. *Present and Future Sources of Water Supply.* http://www.epwu.org/sources.html
17. US Environ. Prot. Agency. 1998. *The 1997 US–Mexico Border Environmental Indicators Report: US Mexico Border XXI Program.* Washington, DC: EPA
18. Varady R, Mack M. 1995. Transboundary water resources and public health in the US–Mexico border region. *J. Environ. Health* 57(8):8–14
19. Lara F, Sánchez R. 1994. *Servicos públicos y movilización social en las ciudades de la frontera: el caso de Nogales, Sonora.* Tijuana: Col. Front.
20. Ingram H, Laney N, Gillilan DM. 1995. *Divided Waters: Bridging the US–Mexico Border.* Tucson: Univ. Ariz. Press
21. US Congr. House Comm. Public Works Transp., Subcomm. Water Resourc. 1988. *Inadequate water supply and sewage disposal facilities associated with "colonias" along the United States and Mexican border: hearings before the Subcomm. Water Res. Comm. Public Works Transp., House Represent., 100 Congr., 2nd Sess., March 11, El Paso, TX; March 12, Brownsville, TX.* Washington, DC: US Gov. Print. Off.
22. Bath CR, Tanski JM, Villarea R. 1994. The politics of water allocation in El Paso County colonias. *J. Borderl. Stud.* 10(1):15–38
23. Sánchez R, Lara F. 1992. *Manejo transfronterizo del agua en los dos Nogales: estrategías para Nogales, Sonora. Rep. Ford Found.* Tijuana: Col. Front. Norte
24. Oppenheimer M, Epstein CB, Yuhnke RE. 1985. Acid deposition, smelter emissions and the linearity issue in the western United States. *Science* 22(4716):859–62
25. Mumme SP. 1988. State and local influence in transboundary environmental policy making along the US–Mexico border: the case of air quality management. *J. Borderl. Stud.* 2:1–17
26. Varady RG. 1985. Air pollution in an arid environment: the effects of copper smelting on the US–Mexico border region. In *Arid Lands: Today and Tomorrow. Proc. Int. Res. Dev. Conf., Tucson, AZ, Oct. 20–25,* ed. E Whitehead, CF Hutchinson, BN Timmerman, RG Varady, pp. 1277–86. Boulder, CO: Westview
27. Chávez O. 1998. *Draft Report on the*

State of the Mexican Border Environment. Ciudad Juárez, Mex: Inst. Tecnológico Estud. Superiores de Monterrey
28. Applegate HG, Bath CR. 1985. Hazardous and toxic substances as part of United States–Mexico relations. In *The US and Mexico: Borderland Development and the National Economies*, ed. LJ Gibson, A Corona Rentería, pp. 226–42. Boulder, CO: Westview
29. Mumme SP. 1986. Complex interdependence and hazardous waste management along the US–Mexico border. In *Dimensions of Hazardous Waste Politics and Policy*, ed. CE Davis, JP Lester, pp. 223–37. Westport, CT: Greenwood
30. Kelly M. 1997. *Rio Grande/Río Bravo Case Study on Transboundary Water Resources.* Montréal: Comm. Environ. Coop.
31. Reynolds K, Kourous G. 1998. Farmworkers: an overview of health, safety and wage issues. *Borderlines* 6(8):1–5
32. Kourous G. 1998. Occupational health and safety in the maquiladoras. *Borderlines* 6(6):1–6
33. Sánchez RA. 1990. Health and environmental risks of the maquiladora in Mexicali. *Natl. Resour. J.* 30:163–86
34. US Environ. Prot. Agency. 1996. *Border XXI Framework Document.* Washington, DC: US EPA
35. Liverman D, Wilder M, Patterson M, Vasquez M. 1997. *Land use change in Mexico.* Presented at Int. Congr. Lat. Am. Stud. Assoc. (LASA97), 20th, Guadalajara, Mex.
36. Morrison J. 1997. *Restoring the Colorado River Delta.* Oakland, CA: Pac. Inst. Stud. Dev. Environ. Secur. 82 pp.
37. Glenn EP, Lee C, Felger R, Sengel S. 1996. Water management impacts on the wetlands of the Colorado River Delta, Mexico. *Conserv. Biol.* 10(4):1175–86
38. Comm. Environ. Coop. 1998. *Advisory Panel Report on the Upper San Pedro River Initiative.* Montréal: Comm. Environ. Coop.
39. Sheridan T. 1996. *Arizona: A History.* Tucson: Univ. Ariz. Press. 434 pp.
40. Tutino J. 1986. *From Insurrection to Revolution in Mexico: Social Bases of Agrarian Violence, 1750–1940.* Princeton, NJ: Princeton Univ. Press. 425 pp.
41. Lorey DE, ed. 1990. *United States–Mexico Border Statistics Since 1900.* Los Angeles: UCLA Lat. Am. Cent. Publ., UCLA Prog. Mex. 475 pp.
42. Meyer MC. 1984. *Water in the Hispanic Southwest: A Social and Legal History, 1550–1850.* Tucson: Univ. Ariz. Press. 189 pp.
43. Cummings R. 1972. *Water Resource Management in Northern Mexico.* Baltimore: Johns Hopkins Univ. Press. 68 pp.
44. Lorey DE, ed. 1993. *United States–Mexico Border Statistics Since 1900: 1990 Update.* Los Angeles: UCLA Lat. Am. Cent. Publ., UCLA Prog. Mex.
45. Dunn TJ. 1996. *The Militarization of the U.S–Mexico Border, 1978–1992: Low-Intensity Conflict Doctrine Comes Home.* Austin, TX: Cent. Mex. Am. Stud. Books, Univ. Tex. 307 pp.
46. Wright A. 1991. *The Death of Ramon Gonzalez: the Modern Agricultural Dilemma.* Austin, TX: Univ. Tex. Press. 337 pp.
47. Cornelius W. 1981. *Mexican Migration to the United States: The Limits of Government Intervention.* La Jolla, CA: UCSD Prog. US-Mex. Stud. 77 pp.
48. Durand J, Massey DS. 1992. Mexican migration to the United States: a critical review. *Latin Am. Res. Rev.* 27(2):3–42
49. Sklair L. 1989. *Assembling for Development: the Maquila Industry in Mexico and the United States.* Boston: Unwin Hyman. 256 pp.
50. Sanderson SE. 1986. *The Transformation of Mexican Agriculture: International Structure and the Politics of Rural Change.* Princeton, NJ: Princeton Univ. Press
51. Ganster P, Walter H, eds. 1990. *Environmental Hazards and Bioresource Management in the United States–Mexico Border-*

lands. Los Angeles: UCLA Lat. Am. Area Cent. 483 pp.
52. US Gen. Account. Off. 1992. Pesticides: comparison of US and Mexican pesticide standards and enforcement. In *Report to the Chairman, Committee on Agriculture, House of Representatives.* Washington, DC: US Gen. Account. Off. 10 pp.
53. Vargas R, Bauer M, eds. 1993. *México–Estados Unidos: energía y medio ambiente.* Mexico: Univ. Nac. Autón. Méx. 259 pp.
54. Lustig N, Bosworth BP, Lawrence R. 1992. *North American Free Trade: Assessing the Impact.* Washington, DC: Brookings Inst.
55. Thorup CL. 1991. The politics of free trade and the dynamics of cross-border coalitions in US–Mexican relations. *Columbia J. World Bus.* 26(2):12–26
56. Ingram H, Milich L, Varady RG. 1994. Managing transboundary resources: lessons from Ambos Nogales. *Environment* 36(4):6–9, 28–38
57. Bocco G, Sánchez RA, Riemann H. 1993. Evaluación del impacto de las inundaciones en Tijuana (Enero de 1993): uso integrado de percepción remota y sistemas de información geográfica. *Rev. Front. Norte* 10(5):53–83
58. Applegate HG. 1984. Transfrontier air pollution along the United States–Mexico border. *Environmentalist* 4:219–27
59. Shabecoff P. 1992. *A Fierce Green Fire: The American Environmental Movement* New York: Hill & Wang. 352 pp.
60. Simonian L. 1996. *Defending the Land of the Jaguar.* Austin: Univ. Tex. Press. 326 pp.
61. Mumme SP. 1986. Engineering diplomacy: the evolving role of the International Boundary and Water Commission in US–Mexico water management. *J. Borderl. Stud.* 1(1):74–108
62. Mumme SP. 1992. New directions in United States–Mexican transboundary environmental management: a critique of current proposals. *Nat. Resour. J.* 32:539–62
63. Varady RG. 1991. *Are EPA and Residents of the US–Mexico Border Speaking the Same Language? Testimony at public hearings on the Integrated Border Environmental Plan (IBEP) by US EPA and SEDUE, Nogales, Ariz., 26 Sept* Nogales: Secretaría de Desarrollo Urbano y Ecol.
64. US Environ. Prot. Agency. 1989. *The Potential Effects of Global Climate Change on the United States.* Washington, DC: US EPA. 689 pp.
65. Comm. Environ. Coop. 1998. *Commission on Environmental Cooperation—Profile.* http://www.cec.org/english/profile
66. Milich L, Varady RG. 1998. Managing transboundary resources: lessons from river-basin accords. *Environment* 40(8): 10–15, 35–41
67. N. Am. Dev. Bank. 1998. *N. Am. Dev. Bank News* 3(6). http://www.nadbank.org/
68. Mumme SP, Moore ST. 1997. *Innovation prospects in US–Mexico border water management: the IBWC and BECC in theoretical perspective.* Presented at Meet. Assoc. Borderl. Scholars, 23–26 April, Albuquerque, NM
69. Milich L, Varady R. 1999. Openness, sustainability and public participation: new designs for transboundary river-basin institutions. *J. Environ. Dev.* 8(3):258–306
70. Udall Cent. Stud. Public Policy. 1999. *CECnet Archives.* http://listserv.arizona.edu/lsv/www/cecnet.html
71. Calva JL. 1993. *La disputa por la tierra: la reforma del artículo 27 y la nueva ley agraria.* Mexico City: Distrib. Fontamara. 244. pp.
72. Cornelius WA, Myhre D, eds. 1998. *The Transformation of Rural Mexico: Reforming the Ejido Sector.* La Jolla: UCSD Cent. US-Mex. Stud. 437 pp.
73. Camp RA, ed. 1996. *Polling for Democracy: Public Opinion and Political Liberalization in Mexico.* Wilmington, DE: SR Books
74. Torres B. 1997. Transnational environmental NGOs: linkages and impact on policy.

In *Latin American Environmental Policy in International Perspective*, ed. GJ McDonald, DL Nielsen, MA Stern, pp. 156–81. Boulder, CO: Westview
75. Hogenboom B. 1996. Cooperation and polarisation beyond borders: the transnationalisation of Mexican environmental issues during the NAFTA negotiations. *Third World Q.* 17(5):989–1005
76. Zabin C. 1997. Nongovernmental organizations in Mexico's northern border. *J. Borderl. Stud.* 12(1–2):41–65
77. Barry T. 1995. *Zapata's Revenge: Free Trade and the Farm Crisis in Mexico.* Boston: South End. 317 pp.
78. Barkin D. 1994. Las organizaciones no gubernamentales ambientalistas en México. In *La diplomacia ambiental: México y la Conferencia de las Naciones Unidas sobre Medio Ambiente y Desarrollo*, ed. A Glender, V Lichtinger, pp. 342–63. Mexico: Secr. Relac. Exter., Fondo Cult. Econ.
79. Kelly ME. 1992. Needs of nongovernmental organizations (NGOs) and empowering NGOs to participate effectively. In *The US–Mexico Border Region Under Stress: a Binational Symposium on Ideas for Future Research. Proc. Symp. Spons. Ford Found., Oct. 1991, Guaymas, Mexico, Sess. 6*, ed. RG Varady, pp. 41–47. Tucson: Udall Cent. Stud. Public Policy
80. Sánchez R. 1993. Public participation and the IBWC: challenges and options. *Nat. Resour. J.* 33(2):283–98
81. Lemos MC, Luna A. 1999. BECC and public participation in the US–Mexico border: lessons from Ambos Nogales. *J. Borderl. Stud.* (XIV)1:43–64
82. Lavanderos CH, ed. 1999. *Recursos: A Directory of US Organizations and Institutions Dedicated to Advancing Mutual Understanding with Mexico.* Mexico: Bibl. Benjamin Franklin. 193 pp.
83. Browne H, ed. 1997. *Cross Border Links: A Directory of Organizations in Canada, Mexico, and the United States: 1997 Environmental Directory.* Albuquerque, NM: Interhemisph. Resour. Cent. 67 pp.
84. Browne H, ed. 1997. *Cross Border Links: A Directory of Organizations in Canada, Mexico, and the United States: 1997 Labor Directory.* Albuquerque, NM: Interhemisph. Resour. Cent. 60 pp.
85. Hayes R, ed. 1998. *Cross Border Links: A Directory of Organizations Around the Globe: 1998 Fair Trade and Sustainable Development Directory.* Albuquerque, NM: Interhemisph. Resour. Cent. 129 pp.
86. Schmidt S, ed. 1995. *United States–Mexico Border Environmental Directory/ Directorio ambiental fronterizo México-Estados Unidos.* El Paso, TX: Cent. Interam. Border Stud. 326 pp.
87. Mumme SP. 1993. Innovation and reform in transboundary resource management: a critical look at the International Boundary and Water Commission, United States and Mexico. *Nat. Resour. J.* 33:93–120
88. Colonias to Air Water Grievances. 1995. *El Paso Times*, 5 Dec.
89. Udall Cent. Stud. Public Policy. 1999. *BECCnet Archives.* http://listserv.arizona.edu/lsv/www/beccnet.html
90. Border Environ. Coop. Comm. 1999. *Border Environment Cooperation Commission—Projects.* http://cocef.interjuarez.com/
91. Varady RG, Colnic D, Merideth R, Sprouse T. 1997. The US–Mexico Border Environment Cooperation Commission: collected perspectives on the first two years. *J. Borderl. Stud.* 11(2):89–119
92. Perry DM, Sánchez R, Glaze WH. 1998. Binational management of hazardous waste: the maquiladora industry at the US–Mexico border. *Environ. Manage.* 14(4):441
93. Reed C. 1998. Hazardous waste management on the border. *Borderlines* 6(5):1–6
94. Dedina S, Young E. 1995. *Conservation and Development in the Gray Whale Lagoons of Baja California Sur, Mexico.* Washington, DC: Mar. Mamm. Comm.

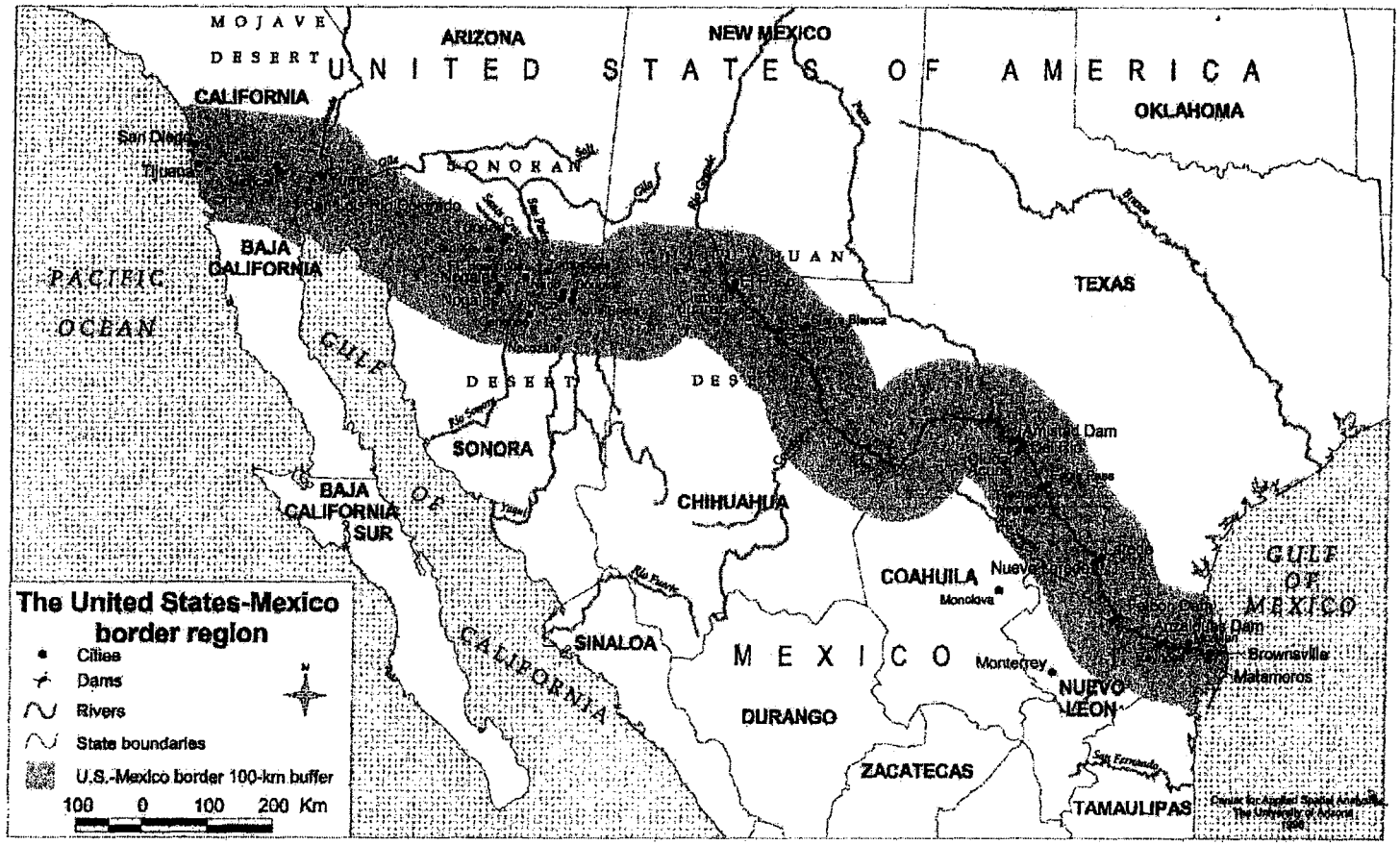

Figure 1 Map of the United States-Mexico border region.

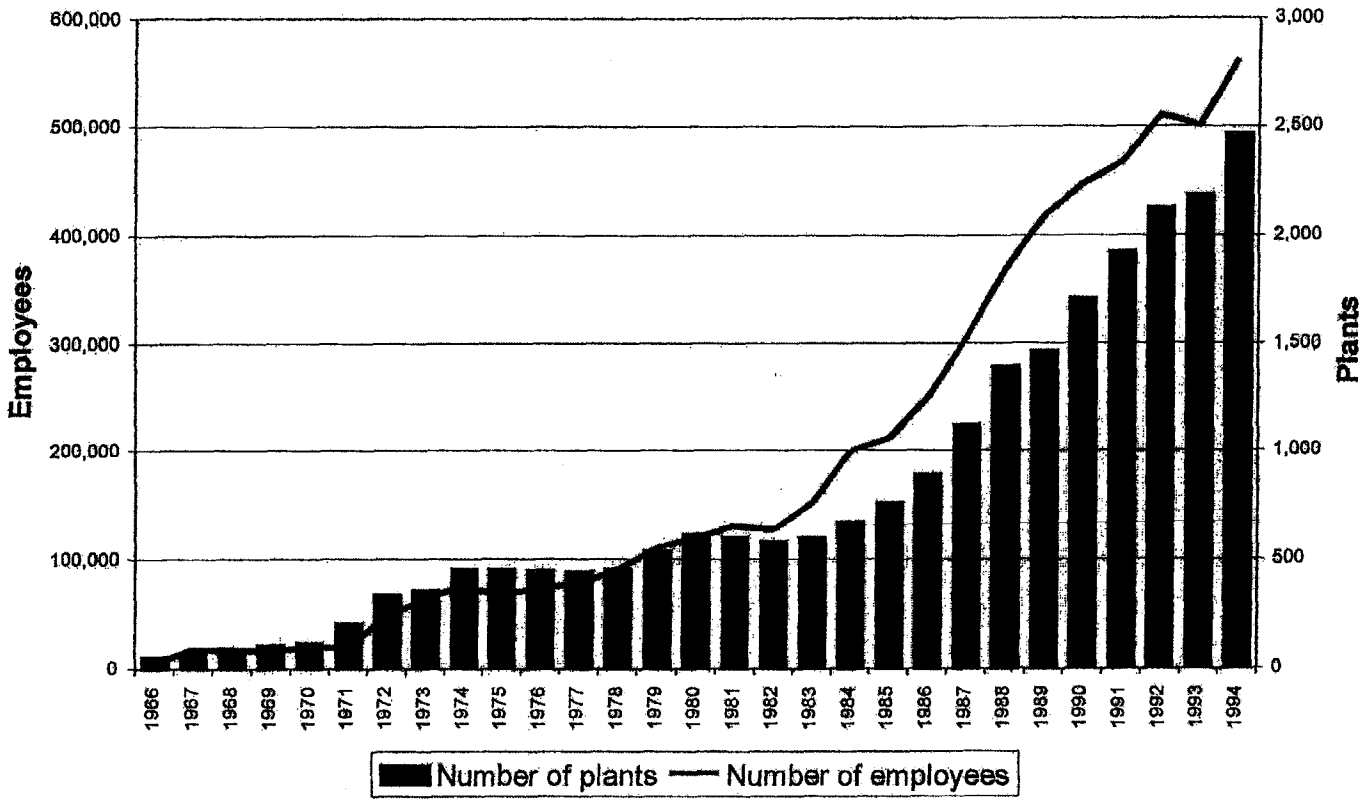

Figure 2 Growth in maquiladora manufacturing in Mexico (data from Lorey 1993).

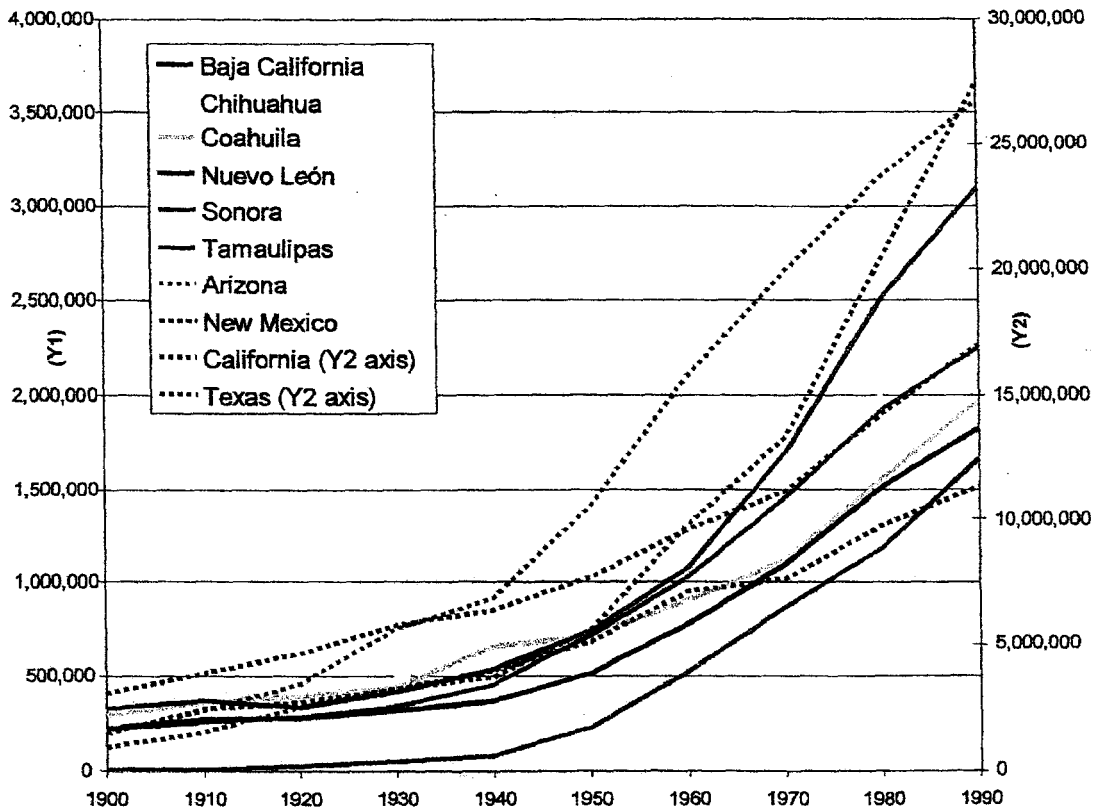

Figure 3 Population of United States-Mexico border states (data from Lorey 1993).