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A Case Study of Two Mexican Biosphere Reserves

The Upper Gulf of California and Colorado River Delta and the El Pinacate and Gran Desierto de Altar Biosphere Reserves

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The Sonoran Desert straddles the Mexico–United States border and encompasses southern Arizona and most of Baja California and the Gulf of California (Sea of Cortez). The Sonoran Desert forms a diverse landscape of terrestrial, freshwater, and marine ecosystems. It is the most tropical of North America's four great deserts and includes desert scrub and grassland, riparian habitats, marine and coastal ecosystems, and patches of tropical deciduous forest that penetrate from the south. This desert covers 120,000 square miles (330,000 sq km), not counting the 109,961-square-mile (283,000 sq km) Gulf of California. The northern gulf is a unique body of water in many ways. High nutrient levels, shallow waters, and strong tidal mixing combine to make it one of the most productive marine regions in the world.[1]

The region's drylands and maritime habitats are tightly linked both ecologically and economically. Originating in the Rocky Mountains, the Colorado River's 1,700 mile (2,800 km) journey to the Gulf of California is most powerfully felt in the Sonoran Desert, where the river winds like a lifeline, matriarch to the ecological and human history of the American Southwest, draining a basin of 244,000 square miles and supplying water to 30 million people, irrigating 3.7 million acres (1.5 million hectares) of farmland, and linking the desert and gulf. The ecological integrity of the Sonoran Desert and

the Gulf of California are threatened by a number of factors, including the reliability of Colorado River water, groundwater overdraft, habitat conversion, pressure from fisheries, unsustainable agriculture and ranching, the introduction of exotic species, and narcotrafficking and related military activities. About 60 percent of the native vegetation of the Sonoran Desert has been converted or destroyed, for example, and nearly all of its rivers have been diverted or dried over the past century.[2]

In response to these threats, nearly three million hectares on both sides of the Arizona-Sonora border have been designated as national parks and monuments, national wildlife refuges, and biosphere reserves. Two biosphere reserves, the Upper Gulf of California and Colorado River Delta Biosphere Reserve and the El Pinacate and Gran Desierto de Altar Biosphere Reserve, which were established in Mexico in 1993, provide protection for over half of this land area, 1.66 million hectares. This chapter discusses the creation and operation of these reserves and the interaction of scientific research and politics in establishing them.

Several questions are at the heart of an assessment of the evolution of science and policy and their interaction in this case. How did knowledge about the threats to the ecosystem evolve, and how did it lead to political action? How has the Mexico–United States border location of the reserves affected their creation and management? How has domestic politics affected international commitments? Given the importance of economic activity in the region, how did the goals of preserving ecosystem health and economic activity interact? What role did local organizations, grassroots groups, nongovernmental organizations, and others play in the formation of the reserves? How successful has the creation of the reserves been in helping to restore and maintain the ecological and societal well-being of the region?

SCIENTIFIC ISSUES SURROUNDING BIOSPHERE RESERVES

The delta of the Colorado River was once one of the richest areas of biodiversity in North America, supporting a marshland and estuary system of 1.9 million acres.[3] Early authors describe an abundance of condors, pronghorns, and bobcats in the delta.[4] Today, almost all of the rich riparian systems (and the large mammals) of the Lower Colorado River and its delta are gone, and the delta has been transformed from a lush subtropical wilderness to a moonscape of sun-baked mud. The twenty dams and thousands of miles of canals, levies, and dikes have converted the river into a highly controlled plumbing system in which virtually every drop is managed. Before the filling of the Hoover Dam (creating Lake Mead), the delta experienced a perennial discharge from the Colorado River. By the time Glen Canyon Dam was

completed in 1962, regular input of Colorado River water to the delta and upper gulf had completely ceased. For twenty years after completion of Glen Canyon Dam, as Lake Powell filled, virtually no water from the river reached the sea. In 1968, flow readings at the southernmost measuring station on the river were discontinued, since there was nothing to measure.

Due to the greatly reduced freshwater flow into the delta, the powerful tides of the Gulf of California began to overwhelm the river channel. Today, during spring tides, seawater creates an estuarine basin thirty to thirty-five miles up river, killing most of the freshwater flora and fauna that used to live along the lowermost river corridor.[5] The spectacular El Niño of 1983–1984 brought several years of heavy precipitation that could not be contained by the twenty dams along the Colorado River. During these years, approximately sixteen million acre-feet of water flooded the delta, and the Colorado River once again reached the Gulf of California.[6] Although this flood was a disaster for the urban and agricultural economy of the Mexicali Valley, it was highly beneficial for the native vegetation and fauna, the return of which was remarkable. As a result of these floods, four freshwater/brackish wetland regions were recreated and continue to persist in the delta.

Even though little water now crosses the border into Mexico, the sixty-mile stretch of the river's channel that runs from Morelos Dam to the Gulf of California maintains five times more native wetlands and natural riparian habitat than does the entire Lower Colorado River in the United States. The only true Sonoran Desert wetland left north of the border is the Bill Williams River at Lake Havasu, and the Colorado River Delta is now the last small refuge for Lower Colorado River riparian gallery forest habitat.

Water has always been the ultimate limiting factor in the Sonoran Desert. The region of the biosphere reserves addressed in this chapter lies in the Lower Colorado River Valley region, which is the hottest and driest subdivision of the Sonoran Desert. This region experiences summer highs that may exceed 120°F, with soil surface temperatures up to 180°F. Annual rainfall in this region is less than three inches, with up to three years passing with no rainfall at all in some areas. The rich riparian forests that once crisscrossed the Southwest, including the state of Sonora, are now rare, due to urban growth, agriculture, ranching, surface water diversion, and overpumping of groundwater. The development of powerful mechanized pumps in the 1920s led to massive groundwater overdraft in agricultural areas throughout the Sonoran Desert. Today the overdraft in this region averages 1.25 million acre-feet per year.[7] The Costa de Hermosillo (Sonora) irrigation district peaked at 887 pump-powered wells supplying groundwater to more than 100,000 hectares of irrigated land, exceeding recharge rates by 250 percent. Due to plummeting water tables and saltwater intrusion, millions of acres of farmland have been permanently abandoned throughout the coastal plains of Sonora and southwestern Arizona.

Despite these reductions in freshwater input, the Gulf of California fauna is highly diverse, comprising 5,968 named and described macrofaunal species (i.e., animals larger than a few millimeters in size). Due to the presence of many undescribed invertebrate species, especially in poorly studied taxa (e.g., sponges, tunicates, copepods, planktonic species), this is estimated to be less than 50 percent of the actual animal diversity of the gulf.[8] The northern gulf (from the Colorado River Delta to, and including, the Midriff Islands of Angel de la Guarda and Tiburon) is home to nearly half of this marine life (2,258 macroinvertebrates and 544 vertebrates), including 367 fishes, 7 marine reptiles, 146 aquatic birds, and 24 marine mammals. At least 142 of these northern gulf species are endemic solely to this region.[9]

Islands and coastal wetlands of the gulf are critical habitats for water birds. At least 213 species of birds have been recorded from the delta region alone; 102 of these are waterfowl, and 30 species are known to breed on the delta. At least seventy-four species use the delta as a migratory stopover or winter ground.[10] Included among these is the endangered southwestern willow flycatcher. The two sand islands at the mouth of the delta (Islas Montague and Pelicano) alone provide habitat for forty-two species of shore birds numbering between one and two hundred thousand individuals, and at least eleven bird species breed on Isla Montague. Of the land birds, most are neotropical migrants that use the delta as a stopover. About 163,000 wintering shorebirds use the extensive mudflats of the delta annually.[11] The western population of North America's white pelican, which has been on the decline for many decades, relies on the delta as a migratory stopover. The endangered totoaba and the currently overfished gulf corvina both occur in the delta region, as does the endangered gulf miniature porpoise, or vaquita.

The terrestrial ecosystems of the Sonoran Desert also sustain an extraordinarily high biotic diversity. Five thousand species of vascular plants are reported from the state of Sonora alone—20 percent of Mexico's total flora, in an area comprising less than 10 percent of the country.[12] Other biotic groups are equally rich in the Sonoran Desert: 150 butterfly species, 1,200 moths, 17 hummingbirds, 160 mammals, and 500 birds (roughly half the known number of birds present in the continental United States or in all of Mexico). At least 96 species of reptiles are endemic to the Sonoran Desert, and there are 552 recorded endemic plants in Baja California alone. The deciduous riparian gallery forest of the Sonoran Desert may have the highest breeding-bird densities on the continent, harboring 304 to 847 breeding pairs per 40 hectares.[13]

The spectacular San Pedro riparian corridor, perhaps the healthiest remaining riparian area in the Sonoran Desert, is home to an estimated 400 species of birds, 83 mammal species, and 47 reptile and amphibian species. The "sky islands" of southeastern Arizona and adjacent Sonora are recognized by the International Union for the Conservation of Nature (IUCN)

Box 2.1 Macrofaunal (Animal) Diversity in the Gulf of California

MARINE SPECIES DIVERSITY IN THE GULF OF CALIFORNIA

Invertebrates (excluding copepods and ostracods): 4,853 species (767 endemic to the gulf)
Vertebrates: 1,115 species
- Fishes: 891 species (87 endemic to the gulf)
- Aquatic birds: 181 species (2 essentially endemic to the gulf)
- Marine mammals: 36 species (2 endemic to the gulf)
- Marine reptiles: 7 species (none endemic to the gulf)

Total: 5,968 species (858, or 14.4 percent, endemic to the gulf)

MARINE SPECIES DIVERSITY IN THE NORTHERN GULF OF CALIFORNIA

Invertebrates (excluding copepods and ostracods): 2,258 species (128 endemic to the northern gulf)
Vertebrates: 544 species
- Fishes: 367 species (13 endemic to the northern gulf)
- Aquatic birds: 146 species (none endemic to the northern gulf)
- Marine mammals: 24 species (1 endemic to the northern gulf)
- Marine reptiles: 7 species (none endemic to the northern gulf)

Total: 2,802 species (142, or 5.1 percent, endemic to the northern gulf)

Source: Brusca et al., "Macrofaunal Biodiversity in the Gulf of California (Sea of Cortez)"; Findley et al., "Macrofauna del Golfo de California [Macrofauna of the Gulf of California]."

as one of the great centers of plant diversity north of the tropics. Mexico itself is one of the twelve megadiversity countries (as defined by Conservation International), harboring 10 percent of the planet's biological diversity on only 1.3 percent of the world's land area. The Lower Colorado River supports 24 federally listed (U.S.) endangered/threatened fish species and 67 "at risk" fish species.[14]

Political battles are fought in this region over water and wetlands use, fishing, farming, cattle grazing, and loss of biodiversity. Overfishing in the gulf threatens marine life and has contributed to the destruction of offshore habitats. Most fisheries in the gulf are either exploited to or nearly to their maximum capacity, or they are overexploited. In populated coastal regions, intertidal communities have been decimated by the removal of animals by tourists and visitors and by locals who collect for the "curio trade." Over-

Box 2.2 The Upper Gulf/Delta and Pinacate Biosphere Reserves

The Upper Gulf of California/Colorado River Delta and the El Pinacate/Gran Desierto de Altar Biosphere Reserves lie within the Lower Colorado River Valley subdivision of the Sonoran Desert—the largest, hottest, and driest area of all the Sonoran Desert.

THE UPPER GULF OF CALIFORNIA/COLORADO DELTA BIOSPHERE RESERVE

The reserve is inhabited by 1,048 species of invertebrates (excluding copepods and ostracods), 43 of which are endemic to the reserve, and 379 species of vertebrates (none endemic to the reserve). The reserve also contains 15 species of marine mammals, 230 species of marine fishes, 230 species of fish, 131 species of aquatic birds, and 5 species of marine reptiles. These figures, however, are probably not a fully reliable indication of the gulf's biodiversity. Many species inhabiting the Gulf of California are poorly documented, and the biodiversity of the reserve remains virtually unexplored.

THE PINACATE/GRAN DESIERTO DE ALTAR BIOSPHERE RESERVE

In the Pinacate reserve, sand soils predominate, including the Gran Desierto, the largest dune field in the New World, covering 500,000 ha from the Algodones Dune Fields northwest of Yuma, Arizona, to the great dune fields of El Pinacate and Bahía Adair. The reserve is also home to 200,000 ha of spectacular volcanic formations, with impressive lava flows, one of the greatest concentrations in the world of giant Maar-type craters, and close to 400 cinder cones. Despite the harsh environment, the Pinacate reserve possesses a high biodiversity: 506 species of vascular plants, 38 species of mammals, 237 birds, 44 reptiles, 4 amphibians, and 2 native freshwater fishes have been catalogued from the reserve.

Source: N. Lancaster, R. Greeley and P. R. Christensen, "Dunes of the Gran Desierto Sand-Sea, Sonora, Mexico," *Earth Surface Processes and Landforms* 12 (1987): 277–88; R. S. U. Smith, "Sand Dunes in the North American Deserts," in G. L. Bender, ed., *Reference Handbook of the Deserts of North America* (Westport, Conn.: Greenwood Press, 1982): 481–526.

grazing by cattle has been a serious problem in much of Sonora and Arizona, resulting in degraded riparian areas, increased soil erosion, and the spread of exotic grasses. Ranching experienced a substantial growth in the Pinacate biosphere reserve region until the 1990s. However, the poor quality of this area for ranching is apparent. Nearly all of the permanently or temporarily inhabited farms in the Pinacate had at least a few cattle. The stock range of the Pinacate reserve is low quality, requiring twenty to thirty hectares per animal. When forage is scarce, native plants are consumed, endangering the indigenous flora—overgrazing is evident in some areas. The recent introduction of European and African exotic grasses that out-compete native plants and spread fire is a major threat to the entire region.[15]

Extreme groundwater overpumping is also occurring in the Sonoran Desert. In the Tucson and Phoenix Basins today, groundwater pumpage averages about four times the natural recharge rate.[16] Overall, the overdraft in the Sonoran Desert region averages 1.25 million acre-feet per year.[17] Due to plummeting water tables and salinization, millions of acres of farmland have been permanently abandoned throughout Sonora, the Colorado River Delta, and southwestern Arizona. Overpumping leads to declines in riparian zone water levels, which eliminates key species such as rushes, willows, and cottonwood, allowing mesquite and salt cedar to expand and creating a "desertification" of riparian areas.[18] Regional extirpation has been documented for 36 of the 82 breeding-bird species that formerly used riparian woodlands in the Sonoran Desert.[19] Conservation International estimates that as much as 60 percent of the Sonoran Desert is no longer covered with native vegetation, but is dominated by more than 380 alien species introduced by humans and their livestock. Secondary effects of groundwater overdraft include soil compaction, land subsidence, and fissuring. In some parts of Arizona and Sonora, land has subsided by one meter, causing fissures that extend for more than half a mile. In some areas, subsidence and fissuring are so extensive that roads have been closed for fear that vehicles would disappear into crevices.[20]

THE SOCIAL, POLITICAL, AND ECONOMIC CONTEXT

Most of the Colorado River Delta lies in the state of Baja California. The delta region includes the Mexicali Valley, most of the Colorado River mainstream from Morelos Dam to the gulf, the Río Hardy and its floodplain, the Sierra Cucapá Range, and the Laguna Salada Basin. This region also includes the two border cities of Mexicali (with nearly 1 million people) and San Luis Colorado (160,000 people), as well as many small towns and communal land arrangements called *ejidos*. In the heart of the delta is the Cucapá Indian

communal land, which includes both the Sierra Cucapá and the Laguna Salada floodplain.

In 1904, the "Colorado River Land Company" was formed by six Americans. The company came to own some of the best agricultural land on the delta, rich alluvial soils derived from the river's seasonal flood history. The Mexican government gave the company permission to exploit virtually all of the resources of the delta and the Mexicali Valley. The company brought in illegal immigrants from China to work the land. In 1937, an insurrection movement born in the Mexicali Valley resulted in the expulsion of the company and the distribution of land and water rights among the *ejidos*. By the end of 1937, 44 *ejidos* had been formed in the Mexicali Valley, and 144,000 hectares were allocated to the new communities.[21]

During the years of occupation by Americans and Mexicans, the native Cucapá people that stayed on the Mexican side of the border were never considered in any land or water decisions, despite the fact that they were the original owners of the Mexicali Valley. As the Cucapá (or "River People") lost their lands (and the reliable Colorado River summer floods), they started to segregate and nearly vanished from the delta. Today there are only two to three hundred Cucapá living in the area; most of them live in the border cities, but a few of them (about eighty-five) are still living on the river banks, especially in the settlement of El Mayor.

The El Pinacate and Gran Desierto de Altar Biosphere Reserve has only a few small scattered settlements and between one and two hundred permanent residents. Population density in the reserve is very low (about 0.01–0.02 person/square kilometer). The lack of local employment forces residents to search for work in the nearby cities of Puerto Peñasco, Sonoyta, and San Luis Río Colorado. Basic services are generally lacking, as is access to necessary goods such as food and clothing. The majority of the inhabitants of the reserve are men, whose families choose to live in one of the cities mentioned above. Settlements are concentrated in the northeast region of the buffer zone, near the town of Sonoyta, primarily along two major highways.

Today, the Southwest is dominated by people who have lived in the region for less than a decade. The population of the Sonoran Desert doubled between 1970 and 1990, to nearly 7 million.[22] By the late 1970s, the deltas of all Sonoran rivers had been almost entirely converted to agriculture, and over a million hectares of mesquite, cottonwood, and willow riparian forest and coastal thorn scrub had been destroyed.[23] The progressive salinization of aquifers and increasing cost of water extraction have caused a decrease in land devoted to crop production, and today only about half the cleared land is still used. The rest lies bare with little vegetative cover.

Approximately 23 million people live in the Lower Colorado Basin today and are largely dependent upon water from the Colorado River. By 2020 it is estimated that more than 38 million people will be living in the Lower

Colorado Basin (table 2.1). This is the fastest growth and most massive land conversion in North America's history. There are no signs that this growth is tapering off, although dwindling water supplies may soon begin to slow it down.

U.S. urban communities are heavily dependent on Colorado River water. However, most (about 80 percent) of the Colorado River's water reaching Mexico is used for agriculture (table 2.2). The Mexicali Valley, at the northern end of the modern delta, is one of the most important agricultural regions in Mexico. It maintains 3,000 kilometers of irrigation canals and 17 agricultural drains discharging into the delta. However, emerging cities, especially along the border, are demanding more water for their growing urban needs, and it is probable that the percentage of Colorado River water that goes to agriculture will diminish significantly in coming years.

The Gulf of California is one of the most productive marine ecosystems in the world, and it has supplied the Mexican, U.S., and Asian markets with abundant fish resources throughout the twentieth century. Mexico is the world's sixth largest fish producer. Since the early 1900s, three coastal fishing communities have become established in the northern gulf: San Felipe in Baja California and El Golfo de Santa Clara and Puerto Peñasco in Sonora. By the 1960s, Mexico's offshore shrimp trawling fleet had become the nation's most important fishing sector, politically and economically.[24] Until the late 1980s, shrimp provided the main source of income for the fishing sector in

Table 2.1 Population Projections in the Lower Colorado River Basin

Area	*Year 1990*	*Year 2020*	*Percent Increase*
Arizona	3,665,000	6,980,000	90
Southern California	16,757,000	26,318,000	57
Southern Nevada	800,000	1,630,000	104
Mexico (using Colorado River water)	1,700,000	3,240,000	91
Lower Colorado River	22,922,000	38,168,000	67

Source: Morrison et al., *The Sustainable Use of Water in the Lower Colorado River Basin.*

Table 2.2 Water Use by Sector for the Lower Basin in the United States and Mexico (%)

Use	*Arizona*	*Southern California*	*Southern Nevada*	*Mexico*	*Regional Total*
Urban	24	44	85	7	33
Agriculture/livestock	76	48	15	93	64
Environmental/other	0	8	0.2	0	4

Source: Morrison et al., *The Sustainable Use of Water in the Lower Colorado River Basin.*

these communities and was the catalyst for their growth. In the past two decades, there have been dramatic changes in the targeted species, and as marine-resource exploitation has grown, the number of species harvested has steadily increased.[25] Today the waters of the Gulf of California supply 40 percent of Mexico's total fisheries, and the northern gulf itself provides 15 percent of the national fisheries. Small-scale ("artisanal") fisheries in the gulf contribute more than 25 percent of the national fisheries production of Mexico, and this percentage is growing rapidly. Approximately 150,000 jobs are generated indirectly from small-scale fishery activities. Recent studies estimate that as many as 30,000 fishers (industrial and small-scale) work in the Gulf of California.[26]

In addition to finfish and shrimp, San Felipe and Puerto Peñasco also fish for blue crab and various mollusks (e.g., black and pink murex, clams, scallops, octopus), and fishers in El Golfo de Santa Clara exploit the large clam beds of the delta.

Maquiladoras ("offshore" manufacturing plants, south of the border) have thrived in cities like Tijuana, Mexicali, and San Luis Río Colorado, all of which are dependent on Colorado River water. *Maquiladoras* have priority over water intended for urban uses, and with their high profits, these industries can afford to pay for the water.[27] Some industries have even bought water from treatment plants in the United States, while others are trying to buy agricultural water rights from the Mexicali Valley.[28] These events mark the beginning of a new period, where agricultural activities are being replaced by industrial activities on the border.

In the 1990s, drug trafficking increased considerably within the upper gulf/delta and Pinacate reserves. The physical and climatic characteristics of the region are ideal for this activity—isolated, inhospitable, and rugged, with uninhabited expanses of lava flows and sand dunes. As part of Mexico's war on drugs, the Ministry of Defense (via the army) undertakes patrol activities to combat the narcotraffic. The Ministry of Environment and Natural Resources (SEMARNAT), through the Directorate of the Pinacate Biosphere Reserve, collaborates with the Mexican army. However, this cooperation is largely in the form of mitigating the impacts that are generated on the natural resources during military operations. Military groups working in the reserves are commonly not sensitive to the fragility of the land, causing off-road vehicle damage to the environment.

THE EVOLUTION OF SCIENTIFIC KNOWLEDGE

Although the flora and fauna of the northern gulf is fairly well known, the biota of the biosphere reserve and delta region are largely unexplored. The

coastline in the uppermost gulf is not easily accessed, nor are the expansive mudflats of the delta itself, and fundamental biological exploration has yet to be made in this region. There has never been a comprehensive survey of the flora or fauna of the Colorado delta. Despite the lack of systematic data, the research available has identified numerous threats to the Sonoran Desert and gulf ecosystem in the area of these two biosphere reserves.

Water Quality

Much of the available data on the health of the Colorado River Delta focuses on water-quality problems. Most of the freshwater supply to the reestablished wetlands of the delta derives from agricultural runoff, although some Colorado River surplus water and municipal raw sewage also drains into the river's channel. There are at least 17 agricultural drains in the Mexicali Valley that flow directly into the Colorado River/Hardy River channel. These agricultural waters also carry 70,000 tons of fertilizers each year, and 400,000 liters of insecticides each year across the delta.[29] The salinity of the drains is so high that its water is not tolerated by native riparian species. Hence, large stretches of delta wetland are dominated by salt cedar (a salt-tolerant invasive tree introduced from Asia in the early 1800s to stabilize stream banks in Arizona and California) that has low value for wildlife because few bird species appear to adapt to its use.[30]

Different sources of water to the delta carry a variety of contaminants that are toxic to wildlife and humans. Pesticides are of special concern since the majority of water is derived from agricultural runoffs, but there is no program in place that systematically monitors for a spectrum of pesticides on the delta. In the 1970s, levels of dichlorodiphenyltrichoroethane (DDE), the most persistent metabolite of dichlorodiphenyldichloroethylene (DDT), an insecticide that once was widely used but is now banned almost everywhere, in clams from the Mexicali Valley were as high as eleven parts per million (ppm) (wet weight). DDT was banned from agricultural use in Mexico in 1978, and a subsequent study in the mid-1980s, showed that concentrations of DDE in clams collected from the Mexicali Valley were much lower, averaging less than 0.2 ppm. More recently, in 1998, levels of DDE in clams from the Colorado riverbed of the delta, and agricultural drains, also tested low (<0.2 ppm). However, concentrations of DDE were much higher in birds of the Mexicali Valley, ranging from 0.04 to 11 ppm. Compared with other agricultural valleys in northwestern Mexico, the Mexicali Valley sustains higher levels of DDE.[31]

Other trace elements of concern that are carried to the delta are boron, arsenic, and selenium.[32] Selenium is a naturally occurring element that concentrates in the Colorado River due to high evaporation rates, especially in

the reservoirs. When selenium reaches the lower section of the river and the delta, it can concentrate to levels that are toxic to wildlife. Bioaccumulation to toxic levels causes high rates of embryonic mortality and deformity.[33] High levels of selenium have been reported from water, sediment, and fish tissues throughout the Lower Colorado River.[34] Selenium levels 1.8 to 14.2 times higher than the U.S. Environmental Protection Agency's (EPA) criterion of 5 μg/L for the protection of freshwater aquatic life (8 μg/L in Mexico) have been reported from delta waters and sediments.[35] Recent studies have shown selenium to be low in invertebrate and fish tissues, whereas higher concentrations are found in bird tissues (e.g., double-crested cormorants, where values were near the threshold at which reproductive effects might occur).[36] The periodic high flows of Colorado River water since the 1980s have had the effect of flushing selenium through the riparian system, and selenium values seem to stay low as long as this periodic flushing occurs.

These studies indicate that DDT (DDE) and selenium are present in low concentrations in the delta's riparian system, but concentrate in greater levels higher in the food chain, especially if periodic adequate flushing from the Colorado River does not take place. Contaminants in general, and organochlorine pesticides and selenium in particular, constitute a permanent threat to the delta's wetlands. Although no standardized monitoring program has been implemented in the delta yet, there is awareness of the threat among the residents of the region, especially the Cucapá who regularly consume locally caught fish and waterfowl. In addition, radionuclides apparently are now leaching into the Colorado River from uranium tailings in Utah, but no information exists regarding the transport of these contaminants to the delta.

Reduction of freshwater input from the Colorado River has impacted numerous species of riparian and marine life. Reduction of the brackish estuarine habitat has, in combination with overfishing, driven the totoaba to near extinction. Absence of freshwater may drive the endemic Palmer's Saltgrass, which needs periodic freshwater flooding to germinate, to extinction. Loss of marshland eliminates key habitat used by many species of shellfish and finfish as nursery-ground during their preadult lives.

Fisheries

In 1941, John Steinbeck and Ed Ricketts wrote passionately about the destruction of the Sea of Cortez by fishing trawlers.[37] Little has transpired since then to address their concerns, and fishing pressure in the gulf remains extreme. In the northern gulf, the historical development of this heavy exploitation is enmeshed in a complex political ecology. Beginning in the 1950s, shrimp fishing grew exponentially in the gulf. Until the late 1980s, shrimp provided the main source of income for the fishing sector in these communities and was the catalyst for their growth. In addition to causing an

increase and industrialization of the large-scale, offshore fishing fleet (especially trawl fishing), shrimp fishing also stimulated the growth of the small-scale fishing sector that uses *pangas* (small skiffs powered by outboard motors) as fishing vessels.

Government policies have consistently encouraged the expansion of both the industrial and small-scale fishing sectors. Commercial boats overexploit the offshore waters, and *panga* fishers take shrimp from coastal lagoons and *esteros* before they have even reached reproductive maturity. The number of large shrimp boats in the gulf grew to over 1,200 by 1999, despite warnings as early as the 1970s of a possible crisis resulting from overexploitation.[38] In the late 1980s, catch per unit of effort (CPUE) began to fall dramatically, making shrimp fishing less and less profitable.[39] Production diminished to the point of near financial collapse for the shrimp industry. In Puerto Peñasco alone, the active trawling fleet was reduced from 220 to 60 boats by 1993, when the upper gulf/delta biosphere reserve was established.[40]

The region's fisheries often operate under practically open-access conditions, existing fishing regulations are commonly not enforced, federal subsidies support overcapacity in industrial fleets, the biology of commercial species is poorly known (or unknown), and monitoring programs measuring the ecological impact of Mexico's fishing operations are almost nonexistent. The American Fisheries Society's official list of marine fishes at risk of extinction notes (an underestimated) six species from the Gulf of California (four endemic); all are large serranids and sciaenids, sensitive to overharvesting because of late maturity and formation of localized spawning aggregations.[41] The sciaenids require estuarine habitats in the rapidly diminishing Colorado River Delta for spawning and nursery grounds. The society also lists the entire gulf (especially its northern part) as one of five geographic hot spots in North America, where numerous fish species are at risk; certainly, the same could be said for the invertebrates of this region.

In the Sea of Cortez, reduction of freshwater inflow, chemical pollution from agriculture and urban areas, and coastal habitat destruction have combined with overfishing, use of nonselective fishing gear, and lack of reliable scientific data to drive such highly visible species as the endemic giant croaker-like totoaba and the vaquita porpoise to near extinction, to cause local extirpation of five species of sea turtles, and to substantially reduce the gulf's important commercial finfish and shrimp populations. Many once abundant, but less visible, species, such as the endangered giant brown sea cucumber and many shark species, are now practically gone from the gulf. Cucumbers and sharks have vanished at the hands of local fishers who take them primarily for the Asian market. The black murex snail fishery in Puerto Peñasco alone landed 600 tons in 1993, but by 1999 the catch had fallen to just 90 tons.[42] Though nationally insignificant, this murex fishery

supports a local economy, and this species is also a key predator in the northern gulf rocky shore ecosystem.

Industrial shrimp trawling exacts a harsh toll on the gulf's marine environment. Around a thousand shrimp trawlers annually rake an area of sea floor equivalent to twice the total size of the gulf (in the shallow northern gulf, it has been estimated that every place on the sea floor is dragged with a shrimp net an average of four times per year). This constant bottom trawling damages fragile benthic (bottom) habitats and captures 10 to 30 kilograms of bycatch for every kilogram of shrimp caught.[43] Catch per unit of effort has been declining for decades, while fuel and export subsidies artificially sustain the overcapacity of industrial fishing fleets. Limited scientific and anecdotal information suggests that sweeping changes in benthic community structure have taken place over the past fifty years of these disturbances.[44] Loss of maritime habitats due to coastal development has reduced the rich *esteros* and mangrove communities of the gulf that served as critical spawning and nursery grounds for shrimp and other invertebrate and fish species. Loss of these wetlands also reduces stopover sites for migratory birds and for reptiles such as sea turtles and giant chuckwalla.[45]

Large artisanal fleets operating in nearly open-access conditions also contribute to overharvesting. In the three main communities of the northern gulf, the large commercial shrimp boat fleet has recently fallen to 175 boats, but the small-scale (*panga*) fishing fleet now exceeds 1,300 boats, which exploit over 70 species of fishes, mollusks, and crustaceans. A recent survey by Conservation International Mexico estimated that there are between 9,000 and 18,000 *pangas* active at any one time throughout the gulf. Approximately 40 percent of this harvest is exported to U.S. and Asian markets, primarily in California, Korea, China, and Japan.[46] Not only are the targeted resources diverse, but the fishing methods and the gear employed are also highly variable, including using gillnetting and long-lining, diving with air-delivery compressors, and employing traps. In the northern gulf, gillnet fishing from *pangas,* targeting *chano* and other finfishes, also incidentally captures the critically endangered and endemic vaquita porpoise and sea turtles. Poaching and incidental catch of sea turtles is a problem throughout western Mexico, although turtle-excluder devices are now mandatory (though commonly not employed) for industrial fishing vessels. Sea turtles have been essentially extirpated from the northern gulf. Today, hundreds of artisanal shark fishers roam freely throughout the gulf, and enforcement mechanisms, clear delimitation of take zones, and harvest limits for shark still need to be developed.

One of the greatest threats introduced by narcotraffic is the increase in small fishing boats (*pangas*) in the northern gulf. The number of *pangas* engaged in fishing in El Golfo de Santa Clara in 1996 was 254; today estimates are 400 to 500 *pangas*.[47] Large commercial boats have been virtually

eliminated in El Golfo. Many of the small boats are obtained by local fishers by way of the narcotraffic through the region, because drug traffickers often abandon *pangas* when they have completed their drug runs along the coast. Some fishers may even be paid with a *panga* to lead traffickers through unknown terrain or to transport a drug shipment.

Many of the fisheries issues in the northern gulf have coalesced around the endemic vaquita porpoise. In 1985, scientists working in the region discovered some of the first complete and fresh specimens of the vaquita, or Gulf of California miniature porpoise. This small porpoise was first discovered and described by scientists in 1958 based upon a single skull specimen. The vaquita is endemic to the northern gulf and extremely rare. Its "rediscovery" immediately caught the attention of the environmental community. The vaquita was being caught incidentally in trawls and gillnets, especially illegal nets set for totoaba and legal nets set for shrimp, *chano*, sierra, sharks, and rays.[48] The demise of the charismatic vaquita, coupled with dramatic declines in shrimp and totoaba catch, focused national (and international) attention on issues of overexploitation in the northern gulf.

With the most recent comprehensive estimate of vaquita abundance at just 567 individuals (95 percent confidence interval equals 177 to 1,073), and mortality at an estimated 39 to 84 deaths per year,[49] the vaquita is the most endangered marine cetacean in the world. Based on mortality compiled for El Golfo de Santa Clara, it is estimated that 13 vaquitas are killed annually in shrimp nets, 17 by the *chano* fishery, 7 in nets set for sharks and rays, 2 in nets set for sierra, and few (or perhaps none) in the corvina fishery, for a total minimum annual mortality of 39 vaquitas. Though the primary cause of mortality prior to and in the 1980s was the now illegal ten- and twelve-inch mesh nets set for totoaba, it appears that the shrimping and *chano* fisheries using smaller-mesh-size gillnets pose the most significant threat to this porpoise. The high market value of shrimp increases the challenges for vaquita conservation.

A lack of biological information on vaquita and fisheries and the almost total lack of control over fisheries activities have hindered progress toward protecting the vaquita and toward more sustainable fisheries management in the reserve and northern gulf. Recent studies on small-scale fisheries have provided important insights and suggestions for management of the gulf.[50] In 1996, the IUCN placed the vaquita on its list of critically endangered animals and the Mexican government established an International Committee for the Recovery of the Vaquita (CIRVA). Using current information on vaquita abundance and mortality and fishing activities and zones, CIRVA has made the following recommendations for its recuperation:

- Reduce vaquita bycatch to zero as soon as possible.
- Extend the southern boundary of the upper gulf/delta biosphere reserve

to include the entire range of the vaquita and exclude gillnets and trawlers from the enlarged reserve.

The need to actively involve the fishing sector in the development of regulations and management systems is recognized by the management team of the biosphere reserve, as well as by NGOs working in the region. Many members of the shrimp fishery are interested in modernizing and downsizing the fleet in preparation for an anticipated free-trade pact with the EU. Since an EU free-trade pact would most likely require that diesel and export subsidies be reduced or eliminated, the older and more inefficient boats would become unprofitable anyway. It has also been suggested that funds from multilateral donors such as the Global Environment Fund be used to buy out the older part of the shrimp fleet. The estimated cost to purchase 400 boats and fishing licenses is about $60 million.[51]

The blame for fishery management inefficiencies and failures is not easily addressed and is certainly not unique to Mexico. Throughout the world, the inherent management complexity of marine fisheries commonly has a reverse effect, resulting in increased utilization and misuse of marine resources. In 1995, the Food and Agriculture Organization (FAO) reported that 69 percent of the world's fisheries are fully or overexploited or depleted and in need of urgent conservation and management measures. In Mexico, management of small-scale fisheries has proven to be a great challenge, and it has led to increasing concern as fishery managers and government agencies have worked to integrate the social and economic importance of this sector into management practices. For historical and logistical reasons, small-scale fisheries have been largely neglected in the formulation of national fisheries policies. Small-scale fisheries are particularly important in developing countries where they provide employment opportunities and the bulk of the domestic day-to-day food for most coastal communities.

Other Ecosystem Threats

Cattle production in the Southwest has played a major role in the transformation of grasslands to scrublands, the spread of exotic plants, and the degradation of fragile desert and riparian areas. Many researchers consider the cumulative impacts of cattle grazing to be irreversible. Statistics from Mexico's Comisión Técnica Consultiva de Coeficientes de Agostadero (COTECOCA) confirm that two to five times the recommended stocking rates occur in the state of Sonora.[52] For more than fifty years, grazing issues have led to arguments among cattlemen, conservation biologists, and ecologists. The antibovine faction argues that overgrazing leads to habitat destruction, terracing and erosion on slopes, loss of riparian communities, and increased threat of Old World grass invasions. In Sonora, the widespread

introduction of exotic grasses for grazing has been on a large scale due to government support. Currently, these grasses occur in very low numbers in the biosphere reserves, but they are spreading rapidly toward the region from both the north and south.

At least 384 naturalized non-native plants now occur in the Sonoran Desert region.[53] In addition to plants, at least 5 to 10 mammals, 2 amphibians, 50 to 60 fishes, and several reptiles have been introduced. There are no estimates of how many invertebrates have been introduced to this region. The intentional introduction of numerous species of African grasses (especially Lehmann love grass and buffel grass) in this region has profoundly changed vegetation structure, fire frequencies, and migratory wildlife corridors.[54] Plant species diversity is ten times lower in buffel grass communities, compared with native desert scrub communities. Conversion of desert scrub vegetation to buffel grass pasture also can cause a fourfold reduction in aboveground standing-crop biomass.[55] Lehmann love grass now covers more than 400,000 acres of Arizona. Buffel grass is now the dominant herbaceous perennial in much of the Sonoran Desert, covering at least 2.3 million acres of cultivated pasture and growing wild (feral) in most of the rest of the region.[56] These grasses have already spread over an estimated 600,000 hectares in the state of Sonora, and they are now intruding into Baja California. Ranchers now harvest buffel grass seed stock by hand along Sonora's main highways, where it grows wild throughout the state. At present, buffel grass areas occur in the Pinacate reserve (and in Baja California) in low numbers, but the chance of its spreading, either naturally or by planned introductions, is a growing threat to native communities.

Salt cedar ("tamarisk") was introduced to North America for stream-bank erosion control in the 1850s and has since spread to over 4,000 hectares of riparian habitat. It was naturalized in the Colorado River watershed by the 1920s. A mature salt cedar consumes as much as 800 liters of water per day, 10 to 20 times the amount used by the native species that it has replaced.[57] Bird diversity can plummet when salt cedar replaces native riparian woodlands. One comparison found 154 bird species for every 40 hectares of native vegetation, compared to 4 species per 40 hectares in salt cedar–dominated areas.[58] The islands of the Gulf of California have also been hit hard by the introduction of rats, goats, rabbits, cats, and various invertebrate pests (e.g., cockroaches, ants, crickets), which have decimated native bird and plant communities. It is estimated that 20 percent of the mammals endemic to the gulf islands and 12 percent of the island birds are now extinct.

THE EVOLUTION OF POLICIES TO PROTECT THE RESERVES

Many binational working groups are seeking ways to establish legal assurances for the quantity and quality of Colorado River water needed to sustain

the delta's wetlands. However, a host of institutional impediments challenges the implementation of a conservation plan. The present system of water appropriation for the Colorado River is the result of a complicated history of conflict and negotiation over U.S. water uses, and between Mexico and the United States. River flows are controlled and regulated by a complex legal framework of treaties, interstate compacts, state and federal laws, regulations, Supreme Court and U.S. Department of the Interior decisions, and contracts collectively known as the Law of the River. Environmental considerations have only recently been considered in water management decisions.[59] The complexity and specificity of institutions governing the management of the Colorado River, combined with institutional inertia and political disagreements, have frustrated efforts to implement binational conservation strategies.

Colorado River Water Law

Western U.S. water law has played a critical role in the declining fortunes of the Sonoran Desert and northern gulf ecosystems. Completion of the Hoover Dam in 1935 began the "development" of the Colorado River. Arguments over who would own the water began as soon as the Hoover Dam was proposed, and before the dam was even completed, the Upper and Lower Colorado River Basin States Water Compact had been drafted and signed. Embedded in the Law of the River are two key treaties and countless laws, acts, minutes, and court decisions. The 1922 Colorado River compact allocated 7.5 million acre-feet per year (1 maf = 1,230,000 m^3, or 326,000 gallons) to the Lower Basin states (California, Nevada, Arizona), 7.5 maf/yr. to the Upper Basin states (Utah, Wyoming, Colorado, New Mexico), and 1.5 maf/yr. to Mexico. However, California has always taken more than its allotted 4.4 maf/yr., and by 2001 was using about 5.2 maf/yr. from the river. This has been allowed because of river "surpluses" declared by the U.S. Department of the Interior (the agency that controls Colorado River diversions) over the past decade because of wetter-than-normal weather and because the other states were not using all of their allocations. Utah, for example, currently draws about half its entitlement of 1.7 maf/yr. In the late 1990s, the Department of the Interior negotiated with California an agreement to limit that state's use of Colorado River water to the original allocation. In January 2003, when the state failed to comply with the first step in implementing the accord (a plan to transfer water from Imperial Valley farmland to the city of San Diego), the federal agency cut the flow of river water to California by more than 260 billion gallons.[60]

The 1944 United States–Mexico Water Treaty guaranteed Mexico 1.5 maf/yr. from the Colorado River (plus another two hundred thousand acre-feet in wet years, and a reduction of two hundred thousand acre-feet during

drought years), but was silent on water quality. A 1973 amendment to the treaty (Minute 242) guarantees Mexico relatively pure water (an obligation the United States has, arguably, never lived up to). Both the water compact and the treaty were based on river-flow data from 1910 to 1920, which we now know was one of the wettest decades in the history of the Colorado River, during which a mean flow of about 20 maf/yr. occurred. Averaged out over many decades, the mean flow of the river is closer to 13.2 maf/yr. As a result, the "paper rights" to Colorado River water actually grant more than the amount that is normally available.

Until very recently all legal instruments dealing with the Colorado River focused on urban and domestic issues and farming and ranching, with no concern for environmental issues. In an attempt to partially correct this omission, in December 2000, Minute Number 306—the "Conceptual Framework for the United States–Mexico studies for Future Recommendations Concerning the Riparian and Estuarine Ecology of the Limitrophe Section of the Colorado River and Its Associated Delta"—was signed.

Regulating Fisheries

After the passage of Article 27 of the Mexican Constitution in 1933, the government claimed all rights to commercial exploitation of resources within inshore waters. This same year, the Ley General de Cooperativas (General Law of Cooperatives) was passed, and with it began an era of fishery cooperatives. The government bought out private companies operating in coastal inshore waters and established some of Mexico's first cooperatives. It also integrated local cooperatives and packing plants into a government-owned system to produce fishery resources, primarily shrimp, for export purposes. Cooperatives not only offered access to credit for equipment and guaranteed fishing permits and access to fishing grounds, but also reduced the uncertainties of fishing. The cooperatives, in theory, are based on a share system in which all participants share a portion of the profit, even if the profit is not large. These advantages enabled cooperatives to quickly recruit many rural fishers.

During President Echeverría's administration (1970–1976), government policies encouraged the expansion of the *panga*, or "artisanal," fishing sector, and small-scale fishing cooperatives were formed.[61] *Panga* fishers were the principal exploiters of the giant gulf corvina-like totoaba. The large spawning aggregations of totoaba in the delta region made it easy prey for *panga* fishers, and by the late 1960s its populations had been decimated. In 1975, the totoaba became Mexico's first endangered (listed) marine fish species, and its fishery was banned. *Panga* fishers also took to the coastal lagoons and *esteros* to fish for shrimp, a practice that has long been banned in the United States because these are critical habitats that serve as "grow

out" nurseries for shrimp and many finfish species. In these shallow nursery areas, Mexican fishers capture juvenile shrimp before they have yet had a chance to reproduce. As of 2001, fewer than three thousand *panga* permits existed in Sonora, but an estimated 9,000 fishers were operating along this coast on any given day.

During the 1970s, the selling price of shrimp increased significantly and a large portion of the population of San Felipe and Puerto Peñasco began fishing for shrimp. There was a large influx of people from inland Mexico to these communities—a new "gold rush" was taking place, but this time it was "pink gold" or "oro rosado," as the large commercial shrimps (*Penaeus spp.*) came to be known. The Gulf of California was experiencing a booming harvest of its fishery resources, as the government moved rapidly to maximize production by giving credits and consolidating fishing infrastructure.[62] The number of large shrimp boats in the gulf nearly doubled from 1970 to 1999 (from 700 to 1,200). With this boom also came the necessary establishment of institutions such as the Secretaría de Pesca (PESCA) to enforce newly defined regulations. Trawler and *panga* fleets grew rapidly in the 1970s, despite warnings as early as the 1970s of a possible crisis resulting from overexploitation.[63] Although total shrimp production continued to climb, catch per unit of effort began to fall, making shrimp fishing less and less profitable. Although the country was benefiting from increased overall production, each new *panga* added to the fleet meant increased competition among fishers. Conflicts arising from competition began to grow as resources were divided among more and more users.[64]

By the end of the 1980s and beginning of the 1990s, shrimp catches were falling precipitously in the northern gulf.[65] Production diminished to the point of near financial collapse for the shrimp industry. Banks took possession of boats, cooperatives closed, and local residents began searching for other work. Despite increased fishing efforts, the total catch fell 33 percent between 1995 and 1999.[66] In Puerto Peñasco alone, the active trawling fleet was reduced from 220 to 100 boats.[67] Besides the consequences to local economies, this near collapse of the northern gulf shrimp fishery provoked more diversification of the fishing activities of small-scale fishers. Species that were sporadic target catches or that had never been commercialized, such as *chano* (gulf croaker), suddenly became actively fished.[68]

Creating the Biosphere Reserves

By the late 1980s, the northern gulf was experiencing an economic and ecological crisis.[69] A series of multiconstituent workshops was convened, beginning in 1990, to develop an action plan for conservation in the upper gulf/delta region. In February 1993, Wetlands for the Americas called for recognition of the Colorado River Delta as an international reserve in the

Programa Red Hemisférica de Aves Playeras. In March 1993, a proposal to declare the upper gulf and Colorado River Delta a biosphere reserve was presented to the Mexican government by a group of NGOs and government agency officials. PESCA fought against the reserve idea, fearing its economic impact on northern gulf fisheries.

In recognition of the extraordinary biological and cultural importance of the upper gulf and Colorado River Delta ecosystems, in addition to increased international pressure to protect the endemic vaquita porpoise and totoaba, the Mexican government declared this region a 934,756 hectare (2,336,890 acre) biosphere reserve in June 1993; 164,779 hectares (411,948 acres) of this reserve is in the *Zona Núcleo* (core zone). Except for traditional practices by the Cucapá people living in the delta and clam harvesting by local residents, the reserve was to prohibit all commercial fisheries within the core zone and to increase regulations for most fisheries within the buffer zone (*Zona de Amortiguamiento*). In 1995, the reserve was accepted into the United Nations Economic, Scientific, and Cultural Organizations's (UNESCO) Man and the Biosphere (MAB) system of worldwide biosphere reserves, and today it is combined with the Pinacate biosphere reserve as one unit in the MAB Program. The upper gulf/delta biosphere reserve has an official "sister reserve" on the Colorado River in the United States, the Imperial National Wildlife Refuge (U.S. Forest Service). This partnership has proven highly useful in coordinating efforts to protect wildlife, especially migratory waterfowl.

The El Pinacate/Gran Desierto Biosphere Reserve was declared on June 10, 1993, and accepted into the UNESCO-MAB Program in 1995. When the Pinacate biosphere reserve was created, there were three main economic activities in the area: agriculture, ranching, and surface mining. These activities were considered incompatible with the conservation objectives of the reserve. In this dry region of the Sonoran Desert, agriculture is an activity with high economic and environmental cost and low return, and it has resulted in the bankruptcy of many *ejidos*. For this reason, market forces alone are gradually driving agriculture from the area. Currently, agricultural activities within the reserve are at a very low level.

Ranching was regulated immediately after the declaration of the reserve, because it was creating direct environmental degradation, destruction of archaeological sites, and contamination of natural water sources. Since the reserve's establishment, no additional cattle have been allowed into the area. Mining in the reserve was also considered a particularly harmful activity, due to its considerable impact on the landscape. Since the creation of the reserve, all mining activity has been stopped in the core zone, and this activity is now permitted only at two sites in the buffer zone.

Prior to establishment of the Pinacate reserve, there were three other low-level economic activities: extraction of wood, hunting, and tourism. Hunting

and wood extraction were prohibited immediately upon declaration of the reserve, and these are prohibited in both the core and buffer zones. The *ejidatarios* may use wood only for personal purposes, such as cooking. Hunting is permitted only for the local Tohono O'odham people for religious purposes.

Taken together, these activities had been important for the inhabitants of the Pinacate biosphere reserve, and this regulation has driven a search for new productive alternatives for local inhabitants. However, despite these efforts, the enforcement of current laws, and the poor conditions for agriculture within the reserve, the rural communities persist in engaging in low-level irrigated farming and open-range ranching. Some *ejidos* have requested authorization to exploit new sand and gravel quarries for sale to the construction industry.

In May 1997 the Technical Advisory Council of the Pinacate reserve was created with representatives from governmental, social, and academic sectors, as well as representatives from the *ejidos* within the reserve. Through deliberations of the council, negotiations with *ejido* residents have been reinvigorated. The council recommended a study to determine the socioeconomic status of the communities within the reserve and to define new economic activities compatible with the conservation of natural resources. The Colegio de la Frontera Norte (COLEF) was contracted to produce a feasibility study of sustainable projects for Pinacate communities. Among the possibilities suggested, high-priority ideas were those related to tourist activities and the construction of nurseries for the production and marketing of native plants. Projects related to agriculture (such as cultivation of date palms) were not recommended.

There are now several projects related to ecotourism planned within the Pinacate reserve, and negotiations are underway to obtain support for their development. In addition, with support from the Centro de Investigaciones en Biotecnología of the Universidad Autónoma del Estado de Morelos (CIBUAEA), a proposal is being developed for native cacti research and nurseries. Finally, with the support of national and international organizations, programs are being developed for environmental education within the reserve communities, primarily focused on children and youth. However, all of these efforts are in their infancy and need increased funding and partnership support (especially from NGOs) to move forward more rapidly.

Recognizing the limitations of the upper gulf reserve, in the spring of 2001 numerous institutions joined forces to develop a more effective strategic plan for the recuperation of the vaquita porpoise. The plan lays out a strategy for establishing a new protected area that would overlap the existing reserve, but extend beyond it to encompass the majority of the vaquita's known range. The plan also urges enforcement of new Mexican laws established for protected areas (in November 2000) that make it illegal to destroy the sea floor

and to use fishing methods having high incidental capture of nontarget species. With these legal tools in place, elimination of trawling and gillnetting within the reserve becomes an issue of implementation and enforcement, both of which are most effectively done by working directly with fishers.

Reserve managers are incorporating some of the new fishing restrictions into their management plan, including the elimination of trawling activities and banning gillnets with a mesh size under six inches. But today the greatest threat to the vaquita appears to be the *panga* shrimp fisheries that use nets with a two-inch mesh size. This activity will be difficult to eliminate, and alternative ways to fish for shrimp are not clear-cut. If alternatives could be found, certification of these products under the Marine Stewardship Council's certification program could help provide its implementers with an added value for their efforts to save the endangered vaquita. Such certification programs are underway further south in the gulf, with the blue crab fishery (Callinectes spp.). Some experts say banning gillnets immediately is the only chance for saving the vaquita from extinction, whereas others say these nets cannot be eliminated until fishers have alternatives. With a population size smaller than 600 individuals, however, time is running out for the vaquita. Because saving the vaquita is linked to the development of sustainable fisheries and general protection for marine habitats of the region, the vaquita provides a powerful symbol and focus for protecting the entire northern gulf ecosystem.

Assessing the Mexican Biosphere Reserves

From one perspective, the creation of the biosphere reserves in the gulf region seems to be a success story. Although scientific information on the health of habitats and species in the upper gulf was incomplete, evidence of widespread loss of biodiversity was sufficient to provoke the Mexican government to take action to create the biosphere reserves. At least as important in motivating action as concerns about endangered species and habitats were fears that the fisheries would not recover and a critical source of livelihood would be lost. Scientific arguments about the value of biodiversity and the importance of preserving it interacted in complex ways with economic arguments about protecting industries and ensuring sustainable harvesting of resources. The vaquita played a key role in turning the issue from largely a local concern to an international issue. There is now in place a network of organizations dedicated to developing ecotourism, encouraging nature education, protecting wetlands, ensuring sustainable resource use, and protecting threatened and endangered species.

Efforts by NGOs, local stakeholders, and grassroots groups were crucial to the creation of the biosphere reserves and played a key role in formulating proposals, educating local groups, and lobbying the government to take

action. Local stakeholders sharing a commitment and identity, a "sense of place," and a common understanding of the local ecosystem are trying to find ways to use the regional sociopolitical structure to take positive steps toward sustainable economic ventures. Local efforts have centered on seeking sustainable employment for regional inhabitants, ecotourism, sustainable aquaculture (e.g., oyster ranching) and halophyte farming; local initiatives to participate with government to reduce overfishing and fishing that threatens the extinction of key species; and NGO and community efforts to educate local stakeholders in sustainable economic practices.

Important citizen movements are coalescing around the wetlands of the upper gulf/delta reserve. In one of the gulf communities, Puerto Peñasco, where development is literally threatening to consume the entire coast, citizens involved in aquaculture activities and tourism projects are joining together to state their interests and concerns and to learn more about how to protect the ecosystem functions that they depend on. Petitions to government have produced responses. When Puerto Peñasco fishers requested a shortened shrimp season in the 1980s, the government acted. Such efforts are strengthened when they come from unified groups such as those currently emerging in support of the biosphere reserves. With the scientific information provided by the Center for the Study of Deserts and Oceans (CEDO), commercial divers at Puerto Peñasco recently requested that the government ban the black murex fishery for one year, to allow for new recruitment. The government responded by establishing a year moratorium on the take of this species. Effective and strong communication of the issues to government decision makers is one of the major challenges facing the isolated communities of the reserves. In this regard, local NGOs can be of considerable assistance, helping give communities communication tools and a louder voice with Mexico City.

However, lack of clear development guidelines and conflicting interests within the government often result in approval of developments that are not in the long-term interests of the local communities or the biosphere reserves. Recently, for example, representatives of the Federation of Cooperatives of Small-Scale Fishermen from Puerto Peñasco wrote a letter of concern about a tourism megaproject located within the upper gulf/delta reserve that has the potential to destroy one of their prime fishing grounds. Though their complaint was registered, it has not been resolved, and the commercial tourism interests of the area remain strong. Though the upper gulf/delta reserve was established to help in the management of fisheries in the northern gulf, the reserve staff literally has no power to make or enforce decisions with regard to these fisheries.

One of the greatest challenges for managers of Mexican biosphere reserves is to find a balance between the use of the area's natural and cultural resources by local residents and visitors and the conservation of these

resources. One of the most suitable and popular sustainable uses for nature reserves is ecotourism. The advantages of ecotourism over most other activities are obvious to reserve managers and visitors, but sometimes not to the local inhabitants, who are typically reluctant to switch from one well-known activity to another completely new activity. Ecotourism is a new concept in the Pinacate/delta region. Although visitation to these areas has increased since declaration of the biosphere reserves in 1993, the activities conducted by most visitors do not fit the concept of ecotourism and still tend to degrade the resources, although usually on a smaller scale than traditional uses.

Small communities and *ejidos*, such as those in the biosphere reserves, typically lack formal structures and organizations that can facilitate communication and action. An important part of the work of the reserves and supporting organizations in recent years has been assisting in the establishment of such structures. As mandated by the management program, the upper gulf/delta reserve established a Citizens' Technical Advisory Council in 1998. This council is composed of representatives of the different stakeholder groups in the reserve, including nonprofit organizations, scientists, fishers from each community, the tourism sector, and the Cucapá people.

From another perspective, the future of the reserves is partly dependent on increasing the flow of water into the area, and the prospects for that are uncertain at best. Strong political commitment from the United States in securing adequate water to restore the gulf ecosystem has yet to occur. In 1997, the U.S. Department of the Interior and the Mexican Ministry of the Environment and Natural Resources signed a letter of intent recognizing the need for binational cooperation in protecting the reserves and other critical areas along the United States–Mexico border. However, since 2001, there have been no signs of further cooperative conservation efforts from the U.S. administration, and the George W. Bush administration's strong propensity to act unilaterally in international affairs makes it less likely that the United States will work with Mexico to secure sufficient water to protect the reserves. The mismatch between costs and benefits makes cooperation difficult. Since the benefits of action will largely occur in Mexico, while the burdens of diverting water for the delta, rather than consuming it, lie largely in the United States, there are strong political forces arrayed against sending more water south.

One option is to use U.S. environmental law to help secure the reserve's future. Environmental groups have filed lawsuits aimed at protecting Colorado River and delta threatened and endangered species.[70] The North American Agreement on Environmental Cooperation (NAAEC), often refereed to as the Environmental Side Agreement to NAFTA, authorizes citizens, NGOs, and others to bring action to enforce domestic environmental laws and regulations.[71] In December 1999, Defenders of Wildlife and fourteen

other Mexican and U.S. environmental groups notified the U.S. government of their intent to sue the Department of the Interior's Bureau of Reclamation for operating and maintaining dams, reservoirs, and other facilities along the Colorado River in ways that failed to supply sufficient freshwater to the gulf to protect endangered species, particularly the totoaba, vaquita, desert pupfish, Yuma clapper rail, and southwestern willow flycatcher. Plaintiffs argue that the U.S. Endangered Species Act (ESA) authorizes the bureau to allocate water in the Colorado River to protect threatened and endangered species.[72]

As of the writing of this chapter, the case has not been decided, but federal courts have upheld the authority of federal agencies to reallocate water under contract to meet the purposes of the ESA.[73] The Supreme Court has repeatedly held that U.S. laws do not apply extraterritorially unless Congress declares their intent to be otherwise. Plaintiffs argue that they are challenging the application of U.S. laws by a federal agency within the United States that have an impact in another country and that Congress intended that the ESA apply to protecting species outside the United States.[74] A study by Environmental Defense concluded that perennial flows of at least 32,000 acre-feet and pulse flows of 260,000 acre-feet at 3,500 to 7,000 cubic feet per second, on average, every four years would be required to protect the habitat of the threatened and endangered species.[75]

A nonprofit group has been formed in Baja California, Asociación Ecológica de Usuarios del Río Hardy y Río Colorado (AEURHYC, the Ecological Association of Users of the Hardy and Colorado Rivers), represented by the stakeholders in this area: farmers, tourism businesses, the Cucapá people, and Mexican and American tourists. This Mexican grassroots movement is support by several similar organizations in the United States that are also lobbying for more Colorado River water to be delivered to the delta. Scientists and conservation groups from Mexico and the United States have begun to pool efforts to understand the complex issues associated with management of the Colorado River water and the delta region. Numerous meetings have taken place, which involve a wide range of both citizen and government participation alongside scientists, with the ultimate goal of providing high-quality water resources for the restoration of the northern gulf/Colorado River Delta ecosystems.

NOTES

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