



...to the Sea of Cortés: nature, water, culture, and livelihood in the Lower Colorado River basin and delta—an overview of issues, policies, and approaches to environmental restoration

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This paper offers an overview of issues, policies, and approaches to the environmental restoration of the Lower Colorado River Basin and Delta. The observations and analysis are based on a symposium and workshop held in Riverside, California, 29 September to 2 October 2000. The binational Riverside event brought together stakeholders representing most of the relevant interests to discuss perceived problems and solutions to seven topics: historical policy and legal matters, the ecological connectivity of the Colorado River and Delta, the allocation and valuation of the waters of the Colorado River, community and cultural concerns relating to the Delta region, water quality, wildlife conservation, and future directions for the Delta and Upper Sea of Cortés.

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Introduction

For many decades, the region of the Lower Basin and Delta of the Colorado River has been a cauldron of disparate and often contentious views by policymakers, environmentalists, scientists, lawyers, economists, farmers, and Indian tribes, for both the U.S. and Mexican governments. The Delta is where the Colorado River waters that flow over 2000 km meet the Sea of Cortés (Fig. 1). The region hosts a rich ecosystem of fauna and flora—an ecosystem that many argue is dying due to the increasing strains on the waters of the Colorado exerted by rapidly growing western U.S. cities and intensively irrigated agricultural areas in the United States and Mexico. ‘What is to be done?’ is the question for many stakeholders—how should the Colorado River be apportioned in the United States and in Mexico and how do environmental needs fit into the overall equation of river management? What are the implications of water-supply and water-quality issues for legal matters and public policy? What have been the role and responsibility of the U.S. government in ‘saving’ the Delta? What are Mexico’s role and responsibility? What





Figure 1. General map of region.

are the roles of nongovernmental organizations, educational and research institutions, and the private sector? How might these roles evolve? These questions and others have been the subject of much debate in the professional, community, and academic arenas.

This paper summarizes current debates about the Lower Basin and Delta of the Colorado River based on presentations and discussion that took place at the symposium and workshop ‘... to the Sea of Cortés: Nature, Water, Culture, and Livelihood in the Lower Colorado River Basin and Delta’ in Riverside, California, 29 September–2 October 2000.

The ‘... to the Sea of Cortés’ program was a 3-day event in which scholars, policymakers, and interested stakeholders gave presentations and engaged in discussion about many of the issues confronting the Colorado River Delta and Upper Sea of

Table 1. *Plenary speakers and presentation Titles*

Presenter	Presentation title
Robert J. Glennon, <i>Morris K. Udall Professor of Law, The University of Arizona</i>	Historical and Legal Perspectives on the Lower Colorado River Basin and Delta
Edward Glenn, <i>Professor, Soil, Water, and Environmental Sciences & Wildlife and Fisheries Program, The University of Arizona</i>	Ecological Connectivity of the Lower Colorado River Ecoregion and its Delta
Henry J. Vaux, Jr., <i>University of California Division of Agriculture and Natural Resources</i>	Allocating the Waters of the Colorado River: Problems and Perspectives
Elena Chavarría, <i>Director PRONATURA—Sonora</i>	Quando el Río <i>Suena</i> ... Voces Lleva: Community Outreach along the Colorado River Delta
Javier Mosqueda, <i>President, Asociación Ecológica de Usuarios de los Ríos Hardy y Colorado</i>	
David Hayes, <i>U.S. Deputy Secretary of the Interior</i>	Delta Restoration: A Long-Standing Problem in Need of New and Creative Solutions
Saúl Alvarez-Borrego, <i>Profesor Investigador de Ecología, Departamento de Ecología, Centro de Investigación Científica y de Educación de Ensenada</i>	Water Quality in the Colorado River Delta and Upper Gulf of California: An Environmental Binational Issue
Daniel Anderson, <i>Professor, Wildlife, Fisheries and Conservation Biology, University of California at Davis</i>	Perspectives for Wildlife Conservation in the Colorado River Delta Region
José Campoy, <i>Director, Reserva de la Biosfera Alto Golfo de California y Delta del Río Colorado</i>	
Exequiel Ezcurra, <i>Presidente, Instituto Nacional de Ecología*</i>	Water Holes and Conservation Wars: The Pocitos of the Lower Colorado

Cortés¹. The first day of the event, a public symposium, consisted of seven plenary presentations and question-answer sessions attended by some 200 participants from both the United States and Mexico (Table 1). The subsequent two days of the event

¹The '...to the Sea of Cortés' symposium and workshop represents the convergence of the border environment programs of the Udall Center for Studies in Public Policy at The University of Arizona and the University of California Institute for Mexico and the United States (UC MEXUS). For the Udall Center, the event was the third in a series of programs sponsored by the Ford Foundation addressing U.S.-Mexico border environmental issues. The first program was held in Cuernavaca in November 1997 on the subject of the drought of 1995-1996; it was organized by the late Professor Albert Utton of the University of New Mexico School of Law. The second program treated transboundary groundwater issues and took place in La Paz in February 1999; the organizer was Professor Helen Ingram, the Warmingtton Chair at the University of California at Irvine.

For UC MEXUS, the 'Sea of Cortés' event was the third in a series of meetings as part of the Institute's Border Water Program, which was supported by funds from the University of California Office of the President. Established in 1997, the Program arose in response to a growing recognition of the need for binational interdisciplinary approaches from the scientific community to address critical water issues and policy along the California segment of the U.S.-Mexico border. The first meeting, 'The UC-Mexico Salton Sea Workshop', was held on 29-30 October, 1998, in Riverside, California, and the second meeting, 'Water, Energy, and the Quality of Life in the Imperial and Mexicali Valleys', was held on 8-11 November 1998, at the Universidad Autónoma de Baja California in Mexicali, Baja California.

comprised roundtable workshops, in which about 70 participants—invited by the organizers and representing a spectrum of viewpoints—gathered around a single table with featured discussion leaders, discussants, and an open forum for dialogue on the topics addressed in the previous day’s plenary presentations (Table 2).

This paper synthesizes the key issues raised in the symposium and workshops, and documents the spirit of the dialogue that ensued during the various discussions. We attribute speakers and contributors and use direct quotations whenever possible. The

Table 2. *Workshop topics and discussants*

Discussants	Topic
David Getches, <i>Raphael J. Moses Professor of Natural Resources Law, University of Colorado School of Law (Chair)</i> Alberto Székely, <i>International Law Consultant in Mexico and Research Director, Utton Transboundary Resources Center, University of New Mexico</i> William Swann, <i>Attorney at Law</i> Marta Macias Brown, <i>Executive Director, The George & Marta Brown Foundation</i>	Legal and Policy Issues
Juan Carlos Barrera-Guevara, <i>Director Ecoregión Golfo de California, World Wildlife Fund (Chair)</i> John Bernal, <i>Commissioner, International Boundary and Water Commission</i> John Letey, <i>Director, University of California Center for Water Resources</i> Carlos Valdés, <i>Director, Center for Conservation and Use of Natural Resources, Monterrey Institute of Technology and Advanced Studies, Guaymas</i>	The Water Framework: Issues of Ecological Connectivity
Roberto Melville Aguirre, <i>Coordinator, Environment and Society Program, Centro de Investigaciones y Estudios Superiores en Antropología Social (Chair)</i> Jennifer Pitt, <i>Senior Resource Analyst, Environmental Defense</i> Robert Johnson, <i>Director, Lower Colorado Regional Office, Bureau of Reclamation</i> Jamie Tinoco Rubí, <i>Coordinador de Asuntos Fronterizos, Comisión Nacional del Agua</i>	Economic and Resource Allocation Issues
Scott Whiteford, <i>Director, Center for Latin American and Caribbean Studies, Michigan State University (Chair)</i> Stephen Cornell, <i>Director, Udall Center for Studies in Public Policy</i> Steve Cornelius, <i>Director, Sonoran Desert Ecoregion Program, The Sonoran Institute</i> Dale Phillips, <i>Tribal Vice-Chairman, Cocopah Indian Nation</i>	Issues of Culture and Community
Jesús Paniagua, <i>Director, Division of Oceanology, Marine Biotechnology, CICESE (Chair)</i> Mitch Ellis, <i>Refuge Manager, Imperial National Wildlife Refuge, U.S. Fish and Wildlife Service</i> Javier Aparicio, <i>Head, Hydrology Technology Coordination, Instituto Mexicano de Tecnología del Agua</i> Tom Levy, <i>General Manager-Chief Engineer, Coachella Valley Water District</i>	Water Quality Issues

Table 2—Continued

Discussants	Topic
Salvador Galindo Bect, <i>Investigador Oceanográfico, Instituto de Investigaciones Oceanológicas, Universidad Autónoma de Baja California (Chair)</i> Michael Cohen, <i>Research Associate, Pacific Institute for Studies in Development, Environment & Society</i> Kevin Doyle, <i>Director, National Wildlife Federation</i> María Pia Gallina, <i>Subdirectora de Mecanismos de Cooperación de Areas Naturales Protegidas, Comisión Nacional de Areas Naturales Protegidas, Secretaría de Medio Ambiente, Recursos Naturales y Pesca</i>	Issues of Biodiversity and Biotic Resources
Robert Varady, <i>Deputy Director, Udall Center for Studies in Public Policy (Chair)</i> Roberto Sánchez, <i>Associate Professor of Environmental Studies, University of California at Santa Cruz</i> Arturo Herrera Solís, <i>Comisionado, Comisión Internacional de Límites y Agua</i> Kara Gillon, <i>Associate Counsel, Defenders of Wildlife</i> Dale Pontius, <i>Associate Solicitor, Land & Water Resources, U.S. Department of the Interior</i> Stephen Mumme, <i>Professor of Political Science, Colorado State University</i> Alberto Székely, <i>International Law Consultant in Mexico and Research Director, Utton Transboundary Resources Center, University of New Mexico</i>	Looking Ahead: Prospective Issues

viewpoints expressed and reported in these discussions are not necessarily the views of the authors nor of the institutions they represent.

Whose River is it?

Historical and legal perspectives

The Colorado River system is the largest river system in the United States that flows through predominantly arid and semi-arid lands. The river drains a basin of 244,000 km², a region that includes parts of seven U.S. states and two Mexican states (Fig. 1).

The legal framework that has delineated apportionments of the Colorado River to states in the United States and to Mexico is known as ‘the Law of the River’—a combination of statutes, court decisions and decrees, contracts, interstate compacts, and administrative rules and regulations. The 1922 Colorado River Compact is at the heart of the Law of the River, which allocated 7.5-million acre-feet to the Upper Basin states (Utah, Wyoming, Colorado, and New Mexico) and 7.5-million acre-feet to the Lower Basin states (California, Nevada, and Arizona)². Mexico was allocated 1.6 million acre-feet plus an allotment of the annual surplus of the Colorado River. Another core

²We use acre-feet rather than metric units because these are the units employed by the official documents (1 acre foot = ~ 1230 cubic meters).

determinant of water allocation in the Colorado Basin is the U.S.-Mexico Water Treaty. The Treaty was ratified in 1944, following a half-century of controversy and unease between the two countries over the division of Colorado River waters. The Treaty guaranteed to Mexico 1.5 million acre-feet annually but was silent on the general subject of water quality. The water-quality problem, which involved the salinity of the Colorado River water delivered to Mexico, then became the subject of a treaty-like resolution facilitated by the International Boundary and Water Commission (IBWC) and its Mexican counterpart, the Comisión Internacional de Límites y Agua (CILA), the national agencies responsible for transboundary river management. The dispute was resolved in 1972 with the signing of Minute 242, which effectively barred the United States from despoiling water quality below its last diversion point and led to the development of a salt-management and reduction program in the United States.

A final pivotal instrument in the allocation of Colorado River waters was litigation between the states of California and Arizona (*Arizona vs. California*) over the quantities of water to which each was entitled. The ultimate decision favored Arizona by providing it with a Colorado River entitlement of 2.8 million acre-feet plus the waters of the tributaries of that state.

The combined effect of the Compacts, the Treaty of 1944, and the Supreme Court decision in *Arizona vs. California* has been to establish and clarify the initial endowments of the basin states and nations. But many argue, such as longtime observer and policy scholar Stephen Mumme, that the Law of the River is based on 19th century needs. According to Mumme, the 1944 treaty focused on 'endowments; security of supply; agriculture, which was the largest user at the time; 'old' development—not sustainable development; it developed state dominated institutions yet failed to anticipate changing values, different stakeholders, and changing forms of social organization'.

Several current plans suggest ways to get water to the Delta: a proposal by the Pacific Institute, a suit by the Defenders of Wildlife, a recent proposal by attorney Malissa McKeith and Clinton Engineering to retire water rights in Mexico and move them to the Delta, and a proposal by the Tucson-based Sonoran Institute to transfer water rights. University of Arizona law professor Robert Glennon has argued that while legal barriers to a Delta transfer may seem formidable, these barriers can be overcome—or circumvented. According to Glennon, the IBWC could serve as the perfect forum in which a Delta transfer program could be developed, implemented, and administered—without a major overhaul of the Law of the River. With its historically technical focus and its ability to negotiate minutes or provide a forum for a new treaty amendment, the IBWC is an excellent institution candidate for the development and implementation of a transfer-based Delta restoration program. Furthermore, Mumme and others have believed that a Minute issued by IBWC and CILA may be the most appropriate means to build environmental concerns into the legal framework. As is, these observers note, urban and domestic issues are the top priority, and the second is farming and ranching. The environment has been left out in these discussions. In an attempt to partially correct this omission, in mid-December 2000, just 2 months after the Riverside event, IBWC and CILA signed Minute Number 306, 'Conceptual Framework for 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' (IBWC, 2000).

Others have argued that the legal framework should not be changed but that existing U.S. laws should be adhered to more strictly. Water lawyer William Swann argued that property rights and water rights in the United States should be respected and that the focus should remain on the American system. Finally, still others maintained that more should be done through binational cooperation and agreements. This perspective, as represented by Alberto Székely, an international law consultant in Mexico and research director of the Utton Transboundary Resources Center at the University of New Mexico, pointed out that emphasis is needed on a regime of diplomatic cooperation

between the United States and Mexico, and not on individual battles for water: 'The Delta is Mexican property, but it is a perfect candidate to become a site of common heritage. There are many reasons why the United States and Mexico need to come together to restore the Delta'.

U.S. Deputy Secretary of the Interior David Hayes concurred with Székely's plan. Precisely because the Delta belongs to Mexico, he observed, 'many in the United States are inclined to believe that the problems of the region are not *our* problems, the issues are not in our interests. We can find solutions. A recipe of collaboration includes good faith and dealing with consensus. It is appropriate that we join with Mexico and talk about the Colorado River Delta without assumptions about the problems and solutions'.

Allocating and valuing the waters

Modern allocation issues differ fundamentally from issues of even half a century ago, which concerned the equitable division of waters among states and nations. University of California economist Henry Vaux, Jr., posited that resolution of contemporary issues likely requires rethinking existing allocation of the scarce water supplies of the Basin. In one sense, the treaty, compacts, and litigation resolved problems in ways that allowed all parties at interest to gain something, be it an increased allocation or an enhancement of the likelihood of allocation. Reallocations, on the other hand, can take on the characteristics of a zero-sum game, in which the gains to one user must be offset by losses to another. If the current problems of reallocation in the Colorado Basin are allowed to become a zero-sum game, the problems will prove extraordinarily difficult to resolve.

If such reallocations are to occur in the timely way needed to keep the Basin economically vibrant and environmentally stable, institutions will need to be devised that can effect such reallocation in a more timely and less costly way than the institutions of the past. Vaux argued that markets and market-like institutions could provide solutions to difficult issues of allocation. According to Vaux, this approach would offer three advantages: (1) it allows water to be traded on a voluntary basis and avoids command-and-control allocative systems and the bureaucracies needed to support them; (2) water would be directed to the most productive activities, thereby optimizing the economic returns to a scarce resource; and (3) systems of taxes or appropriations can be created to ensure that uses for the public good can compete with consumptive uses.

There is some support for water markets. In fact, water transfers already are occurring. In-state water transfers, such as those between Indian settlements in Arizona, date back to the 1980s. Within the State of Arizona, there have been transfers from agricultural to urban users (Oggins & Ingram, 1990). In fact, according to Robert Johnson of the U.S. Bureau of Reclamation, intrastate transfers are generally not difficult to accomplish; instead it is *interstate* transfers that are thorny and complicated. In 1994 the Bureau of Reclamation began to develop water markets; it drafted regulations and proposed seven guidelines, which were later withdrawn due to a firestorm of objections from Arizona.

There is much debate as to whether water markets can offer the win-win situation painted by Vaux. According to Vaux, past experience suggests that agricultural users of water will offer the most objections to water transfers. Robert Johnson disagreed: 'The big problem may instead be with local communities'. Robert Glennon has argued that the water-market idea is too simplistic and that it could lead to buyouts of water rights, a potentially disastrous outcome. 'The nature of water markets puts a value on certain kinds of users. Water markets will not do a thing for the Delta. There may be no economic value for the water that reaches the Delta'. Johnson posited that 'A perfect-competition market is never going to be achieved with water; therefore, such a market

needs to be highly regulated'. Glennon has suggested that public funds should be invested into more easily-resolvable water-quality issues.

One of the representatives of indigenous nations, Dale Phillips of the Cocopah Indian Tribe, rejected the idea of water markets on spiritual grounds. 'Who can sell the water? Nobody owns water or air The [Cocopah] tribe is fighting for the water; nobody owns the heavens; nobody owns this land . . .'. Elsewhere in the South-west, however, Indian tribes such as the Gila River communities in Arizona, have litigated—often successfully—to secure water rights and the implied authority to sell or trade those rights according to market values (Checchio & Colby, 1993).

Community values

Frequently, discussions of diplomatic, legal, and economic issues occur beyond earshot or full comprehension of those most affected by proposed solutions. The perspectives of local communities are also important. Who are the residents of the Lower Basin and Delta region? What are their ways of life, their means of production, and their hopes and aspirations? What economic interests and cultural values do they embody? The local communities are directly affected by policy; consequently, they become participants by default. To underline those concerns, community organizers Elena Chavarria, the director of Pronatura in Sonora, and Javier Mosqueda, the president of the Asociación Ecológica de Usuarios de los Ríos Hardy y Colorado, urged policymakers, managers, and other stakeholders to always bear in mind the perspectives of the area's communities.

Mosqueda recounted experiences of the past: 'At the end of the half-decade ending in 1983, we experienced several events. The erosion of the river was eating up fertile lands. The impact was not due to an excess of water, but to a lack of water. The main problem was that flows stopped, and when we had emergencies the Delta was not there. This caused great damage'. He continued, 'How can we carry out our activities—our livelihoods—when we lack money and need to engage in a fight against a giant? For 40 years we did not see a river. Now we see one only when there are floods. It's a lot of words, but we need action. The Delta belongs to everybody'.

While many activists call for more community outreach as a way to raise consciousness and understanding, Peggy Turk Boyer, longtime director of CEDO, an environmental education center in Puerto Peñasco, pointed out that 'We need to think more in terms of *government* outreach—that is, education of government officials. People who live with the reality of water scarcity don't need to be contacted as much as people in government who need to understand the value of water at a personal level'. Udall Center director Stephen Cornell agreed: 'We need to bring new understandings and local relativity into institutional decision-making'.

In addition to soliciting views and preferences of the communities that use water, most participants agreed that cultural dimensions of the varieties of water uses need to be addressed. 'Do we eat or play golf?' a participant asked. Consumption and distribution patterns within Mexico and the United States differ greatly. Most observers assume that present water consumption patterns will continue, but is that a reasonable assumption? How will these questions be addressed?

With many existing research programs tied to the physical and natural sciences, how can social-science agendas be accommodated? UC MEXUS director Juan Vicente Palerm and Cornell agreed that new binational research programs should encourage collaboration among investigators from multiple disciplines. Helen Ingram, of the University of California at Irvine, cautioned that 'sometimes research is an excuse for not acting'. There is a need to maintain a balance between the perpetual desire for more and better investigations and the pressing need for action.

How much water does the delta need?

There is immediate need for increasing support for binational, interdisciplinary research on the Colorado Delta region. For many years, scholars and resource managers have conducted studies on various aspects of the ecology, biology, and physiography of the Lower Basin and Upper Sea of Cortés. The other essays in this issue of the journal are a manifestation of the years of research on such issues.

Dr Edward Glenn, a University of Arizona professor of soil, water, and environmental sciences, also the editor of this issue of the *Journal of Arid Environments*, has been among the most active investigators of sustainable management of the Delta ecosystem. Glenn and his colleagues conducted a study of the regenerative abilities of native species of plants in the region based on surplus flows that reached the Delta in 1990s. Their study confirms that deterioration of native habitat on regulated rivers such as the Colorado can be progressive and irreversible, and it is not known if restoring elements of a natural flow regime would by itself permit native species to repopulate riparian zones of the southwestern United States (Zamora-Aroyo, *et al.*, 2000).

Although the entire discharge of the Colorado River is considered to be overapportioned for human use with no water remaining for ecosystem maintenance, maturation of the dam and lake system on the River has led to the return of occasional pulse-releases in the riparian corridor below Morelos Dam (Fig. 2). The River's dams are operated to keep the large reservoirs full and to accommodate electric-power generation, recreation, and storage for downstream water use. Since the filling of the last large reservoir, Lake Powell (behind Glen Canyon Dam), in 1981, large volumes of so-called 'waste spills' have been released to the Colorado River Delta and Upper Gulf of California, partly in response to El Niño Southern Oscillation (ENSO) cycles, which bring above-normal winter or spring precipitation into the lake system. As a result, water has flowed to the Delta in 10 of the 20 years since 1980, releasing approximately 20% of the total river discharge to the sea over those two decades.

Glenn and his team analysed the effects of river discharge on vegetation from 1992 to 1999 and characterized the status of vegetation using remote sensing and ground methods (Zamora-Aroyo, *et al.*, 2000). They found that pulse floods have reestablished cohorts of native trees in a 100-km stretch of the riparian zone of the Delta, from Morelos Dam to the junction of the Colorado River with the Río Hardy (Fig. 2). The extent of vegetation cover in this stretch is responsive to flood flows. These floods seem mainly to wash salts from the riverbanks, allowing the germination of cohorts of native trees and other vegetation following each flood event. Between flood events the native trees appear to exist on subsurface water. This study supports the pulse-flood hypothesis for the establishment of native trees, which states that occasional overbank flooding is necessary to wash salts from the banks to allow mesophytic species to germinate. Otherwise, banksides become too saline for all but the most salt-tolerant plant species. The preliminary findings suggest that the riparian corridor requires 260,000 acre-feet every four years to regenerate trees. To create a perennial flow of water, 50,000 acre-feet per year is required. This totals 115,000 acre-feet on an annualized basis, less than a twelfth of Mexico's annual appropriation of Colorado River water, which is 1.5 million acre-feet.

Most stakeholders agree that this kind of research is important. The work of Glenn and his associates helps bring into focus the relatively modest volume of water that can suffice to support riparian vegetation and stresses that timing is as important as quantity. John Letey, director of the University of California Center for Water Resources, called for a hydrological model to explain the changes in surface flows and subsurface flows and to determine when strategic releases of water should occur. Seconding the importance of timing, Mexican biologist Salvador Galindo reminded participants that the reproductive stages of marine organisms need to be considered



Figure 2. Dam system on the Colorado River.

when determining when a flow should occur. Carlos Valdés, a biologist from the Monterrey Institute of Technology campus in Guaymas, Sonora, maintained that the estimate of water needed to sustain the ecosystem is a minimum standard.

What kind of water?

Even if experts differ in their assessments of how much water is necessary to assure the survival of the ensemble of the Delta's ecosystem, they generally agree that given sufficient investigations, threshold levels can be established; however, the quality of available water is also a key determinant. And whereas quantity can be expressed in a single concept—volume—quality is an attribute that must be measured in multiple ways. Salinity, microbial contamination, chemical pollution, and pH level all influence the marine and estuarine organisms.

In the region, according to marine biologist Saúl Alvarez-Borrego of UABC in Tijuana, the Mexican government faces three formidable quality-related challenges:

rising levels of water salinity; high concentrations of nutrients from agricultural drainage; and contamination from heavy metals, especially selenium.

The only freshwater inflow to the Upper Sea of Cortés is the Colorado River. The Upper Sea of Cortés and Colorado River Delta comprise an area of reproduction and nursery for numerous species of fish, shellfish, and marine mammals, including two endemic species that are now endangered—a once heavily exploited fish known as the totoaba (*Totoaba macdonaldi*) and a small marine mammal, a dolphin known as the vaquita (*Phocoena sinus*). Out of growing concern for the fate of the totoaba and the vaquita, and the unique habitats that support numerous migratory birds, marine mammals, and key fisheries, in 1993 the federal government of Mexico decreed the Upper Gulf of California and Colorado River Delta Region as Biosphere Reserve, which is part of the UNESCO International network of Biosphere Reserves.

With the construction of several dams along the Colorado River, the quantity of freshwater flowing through the Delta and into the Upper Sea of Cortés has been greatly diminished. In fact, there are long periods when no freshwater reaches the Sea at all, creating highly saline conditions and raising water temperatures to such an extent that a number of endemic species are becoming increasingly rare. Commercially valuable species such as shrimp (*Litopenaeus stylirostris*) have also declined in abundance, a trend that recent studies have linked to the loss of freshwater inflows.

The water that has reached the Delta and the Upper Sea of Cortés has included agricultural drainage water with high levels of PO_4 , NO_3 , and SiO_2 (Alvarez-Borrego *et al.*, 1978). In addition, heavy metals also can be found in unusually high levels in the Delta and Upper Sea of Cortés, posing a serious risk to local fauna. Selenium is among the most abundant of these, particularly in the Delta. This metal easily bioaccumulates to toxic levels for wildlife, causing high rates of embryonic mortality and deformity. Other metals, such as boron and arsenic, have also been detected there in high concentrations. Still others, such as manganese, zinc, and aluminum, have been found in sedimentary material from the Colorado River Delta in the Upper Sea of Cortés.

Since the early 1970s, there has been some concern about the possibility of pesticide transport from the Mexicali Valley into the Upper Sea of Cortés. One study that assessed the concentration of pesticides in organisms of the Mexicali Valley at that time found DDT metabolites in specimens of clam (*Chione californiensis*) taken from the irrigation canals (Guardado-Puentes *et al.*, 1973). A follow-up study conducted 10 years later again documented concentrations of DDT in various mollusk species in the canals, although the levels of DDT that were found were lower than those reported a decade earlier (Gutierrez-Galindo *et al.*, 1988).

More detailed studies are needed, Alvarez stated, to evaluate the potential harm of heavy metals, radioactivity, pesticides, and other chemicals in coastal and marine areas of the Upper Sea of Cortés. Hydrologist Javier Aparicio of IMTA, Mexico's national water research institute, also insisted that more research needs to address issues of water quality. Jesús Paniagua, a marine biologist at CICESE, suggested that other factors also need to be examined as well, such as the effects of the shrimp industry on the water quality of the Delta. His colleague at CICESE, Rubén Lara, added that the entire hydrological system, including climatic variations, needs to be monitored.

Wildlife conservation

As we have seen, sufficient and suitably-timed amounts of water of acceptable quality are essential elements of a healthy marine biosystem. The region in question includes a large but decreasing variety of vertebrate and invertebrate species—some, like shrimp and edible fish, have direct economic value, while others, like vaquitas (*Phocoena sinus*) and large birds are more prized for their aesthetic or ecotouristic value. Ironically, just as societies are increasingly appreciating the benefits of biodiversity, demographic

changes and economic development sometimes compromise the natural systems that sustain rich communities of species. Progress hinges on binational collaboration for habitat protection and restoration as well as increased quality and quantity of water flowing into the Delta. Daniel W. Anderson, a biologist at the University of California at Davis, and José Campoy, the director of the Reserva de la Biósfera del Alto Golfo de California y Delta del Río Colorado, explored the issues surrounding wildlife conservation and recommended a series of actions to protect and restore the ecological vitality of the Colorado River Delta.

Migratory birds require ecological connectivity among distantly linked habitats along the so-called Pacific Flyway. The Colorado River Delta remains a critical link in a diminishing chain of habitats along this key continental flyway. Riparian corridors and estuaries of the Delta provide important breeding and wintering grounds to a wide spectrum of resident and migratory birds.

Participants offered different modes of understanding the interconnectivity of the region. For example, the Pacific Institute's Michael Cohen emphasized that understanding the Delta requires a holistic vision with equal consideration of political, ecological, social, and economic issues. Cohen and Richard Brusca, a marine biologist at The University of Arizona, highlighted the need for more research and for the implementation of a widespread, holistic monitoring program. In addition, Brusca called for an all-species inventory of the region to fill in the current knowledge gap that exists about the kinds of marine species that dwell in the Sea of Cortés.

In addition to accelerating basic scientific research, new management strategies should be designed and put in place. As noted, water allocation and quality are the major underlying issues for conservation biologists all along the Pacific Flyway, including the Biosphere Reserve of the Upper Sea of Cortés and Delta of the Colorado River. But if the goal is good water quality for both society and for the support of biodiversity and natural resources, then planning ought to proceed accordingly. To assure success, local communities most directly affected by enhancement efforts should be involved in and benefit from such initiatives. Furthermore, scientists should begin identifying and protecting habitat areas that are critical.

Consistent with recommendations by others, Anderson and Campoy felt that the binational nature of the watershed requires that a binational regulatory body promote conservation. In the immediate future, the IBWC and CILA may be the most viable institutions to take on this task. Secondly, at a national level, they believed that current legislation governing the allocation and use of Colorado River waters should be revised to give 'standing' to the watershed and to elevate to a higher priority the Delta's ecological needs. Recognizing that any legislative effort that addresses the watershed's ecological concerns will be both complex and time-consuming, Anderson and Campoy envisioned 'stopgap' measures to temporarily accomplish ecosystem-based management goals.

Anderson and Campoy argued that if water laws are rewritten or if otherwise effective measures are taken, Mexico needs to ensure that water deliveries to the Delta will be committed to environmental uses. Government agencies and other stakeholders in the United States and Mexico will have to recognize that a healthy Delta and Upper Sea of Cortés will constitute a strong economic gain for all parties. Finally, concurring with previous statements, Campoy and Anderson stressed that planning and execution of ecological protection and restoration should be by all affected constituencies.

María Pia Gallina, subdirectora de Mecanismos de Cooperación de Areas Naturales Protegidas, Comisión Nacional de Areas Naturales Protegidas, Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT), urged more vigorous U.S. participation in preserving the Delta ecosystem. 'Mexico', she argued, 'has taken concrete steps to preserve the richness of the region'. The country has declared a protected area and designated resources to preserve that area. Through its association with UNESCO's

Man and the Biosphere Program, the Delta has been acknowledged as a wetlands of international significance. 'But while Mexico is responsible for the preservation of the ecosystem at the end of the river', Gallina said, 'the United States also needs to be committed'.

Looking ahead: the *pozos*, or waterholes, of the delta as a metaphor for ecosystem resilience

The Gran Desierto, the arid region that hosts the Lower Basin and Delta (Fig. 3), offers a hopeful metaphor for recovery. Exequiel Ezcurra, Mexico's newly appointed President of the Instituto Nacional de Ecología³, noted that among some of the most inhospitable desert saltflats of the Gran Desierto, one can find lush green spots of aquatic plants at sparse intervals. Ezcurra, who first saw this area in the 1970s, noticed these oases in his first visit and has been intrigued by them ever since. Freshwater sprouts to the surface of the desert and wetland vegetation seems to grow miraculously in the middle of the saltflats. These oases support a rich variety of birds and mammals that flock daily to drink from the precious *pozos*, or waterholes. A heterogeneous array of artifacts, including layers of shell middens, clay pottery, stone flakes, and whole *metates* (indigenous grinding stones) also abounds in the vicinity of every single waterhole, suggesting that these areas once supported resident human populations.

The flora of these *pozos* is markedly different from that of the surrounding Sonoran Desert, both in life forms and in geographic origin. In 1983, the *pozos* supported 26 species of vascular plants, many of which showed temperate affinities. Several members of the *pozos*' flora were unexpected in the region, like the Indian Hemp (*Apocynum cannabinum*), *Lythrum californicum*, and the Greasewood (*Sarcobatus vermiculatus*). To Ezcurra and his colleagues, the characteristics of the flora posed a question of the origin of the wetland species. They posited that the *pozos* were colonized by seeds transported from the Colorado River Delta, when the delta was an immense wetland (Ezcurra *et al.*, 1988). Accordingly, Ezcurra hypothesized that the flora of the *pozos* owes its northern affinities and temperate-species composition to the constant inflow of seeds transported down the Colorado River into the Delta and then transported some 100 km from the Delta along the coast of the Upper Sea of Cortés into the Adair Bay.

As mentioned previously, the damming of the Colorado, the overfishing of the Upper Sea of Cortés, and the chemical runoff from agricultural fields have altered the Delta region, leaving a whole ecosystem threatened. But these *pozos*, relics of a different era of the Colorado's flow, provide evidence of the resiliency of ecosystems to withstand the changes brought about by human populations.

Conclusion

Exequiel Ezcurra's *pozos* offer metaphorical hope for the resurgence of a menaced ecosystem, an indication, however small, that the Delta region is more durable and better able to overcome stress than previously believed. But can the resilience of a collection of dispersed microenvironments be extrapolated to a much larger ecological zone—a zone that unlike the isolated *pozos* is subject to intense human activity?

The participants at the Riverside event have offered a large and diverse set of answers to that question. In view of the leap in scale from small waterholes to a vast

³ At the time of the symposium and workshops, Ezcurra was Deputy Director of Research and Collections at the San Diego Natural History Museum.

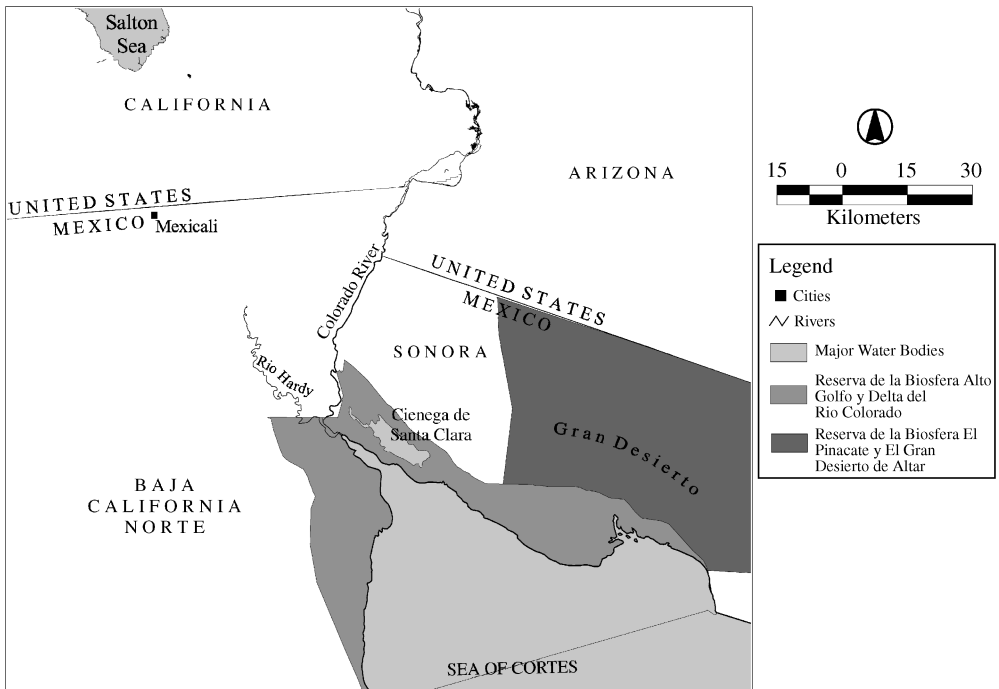


Figure 3. Colorado River Delta.

basin, perhaps not all were as optimistic as Ezcurra. But nearly everyone agreed that some combination of applied science, more skillful management, better-adapted institutions, more convergent binational interests, and committed community-level participation might reduce the problems facing the Lower Colorado Basin and Delta.

These widely varying approaches reflect the disciplines and inclinations of the proponents. The solutions tendered also mirror the interests of the multitude of stakeholders—irrigators, fishing communities, indigenous populations, urban residents, ecotourists, conservationists, officials in Mexico and the United States. That all these voices were represented in Riverside and that so many of them offered courses of action is a promising sign. As former Mexican ambassador-at-large Alberto Székely concluded, ‘This event offered eloquent proof that the ideas are there’. And commenting on the palpable enthusiasm of the participants, who he thought should remain the principal protagonists, he added, ‘If there is a sense of urgency, then a contribution has been made’.

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paper also owes much to the intelligence and careful attention of the rapporteurs: Gwen Alexander, Maria Gutiérrez, and Jen McCormack of The University of Arizona's Udall Center for Studies in Public Policy; and Alison Lee of the University of California at Riverside. The authors acknowledge the late Albert Utton of the University of New Mexico School of Law and Helen Ingram of the University of California at Irvine, who with author Varady were co-principal investigators of the multiyear series of three programs culminating in the Riverside symposium. Finally, the authors wish to thank Peter Johnson in the Center for Applied Spatial Analysis (CASA) at the University of Arizona for producing the maps for this article.

References

- Alvarez-Borrego, S., Rivera, J.A., Gaxiola-Castro, G., Acosta-Ruiz, M.J. & Schwartzlose, R.A. (1978). Nutrientes en el Golfo de California. *Ciencias Marinas*, **5**: 53–71.
- Checchio, E. & Colby, B. (1993). *Indian water rights: negotiating the future*. Water Resources Research Center, The University of Arizona, Tucson, Arizona.
- Ezcurra, E., Felger, R.S., Russell, A.D. & Equihua, M. (1988). Freshwater islands in a desert sand sea: the hydrology, flora, and phytogeography of the Gran Desierto oasis of Northwestern México. *Desert Plants*, **9**: 35–63.
- Guardado-Puentes, J., Núñez-Esquer, O., Flores-Muñoz, G. & Nishikawa-Kinomura, K.A. (1973). Contaminación por pesticidas organoclorados. In: *Estudio Químico sobre la Contaminación por Insecticidas en la Desembocadura del Río Colorado, Tomo I, Reporte Final a la Dirección de Acuicultura de la Secretaría de Recursos Hidráulicos*, pp. 79–200. Universidad Autónoma de Baja California, Ensenada, Baja California, Mexico.
- Gutierrez-Galindo, E.A., Flores-Muñoz, G. & Villaescusa-Celaya, J.J. (1988). Chlorinated hydrocarbons of mollusks of the Mexicali Valley and Upper Gulf of California. *Ciencias Marinas*, **14**: 91–113.
- IBWC (International Boundary and Water Commission) (2000). Minute No. 306, Conceptual Framework for 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, El Paso, Texas, 12 December 2000.
- Oggins, C.R. & Ingram, H.M. (1990). *Does anybody win? The community consequences of rural-to-urban water transfer: an Arizona Perspective*. Udall Center Issue Paper Number 2, May 1990, Udall Center for Studies in Public Policy, The University of Arizona, Tucson, Arizona.
- Zamora-Arroyo, F., Nagler, P., Briggs, M., Radtke, D., Rodriguez, H., Garcia, J., Valdes, C., Huete, A. & Glenn, E. (2000). *Regeneration of Native Trees in Response to Flood Releases from the United States into the Delta of the Colorado River, Mexico*. Report to the United States Fish and Wildlife Service, November 2000.

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Manuscript Page/line	Details required	Author's response
Table 1	Supply footnote.	

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