The Delta of the Colorado River

edited by

David L. Alles

Western Washington University

e-mail: alles@biol.wwu.edu

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Note: In PDF format most of the images in this web paper can be enlarged for greater detail.

Introduction

The delta region begins just beyond the Colorado River's departure from the United States' southern boundary, and includes portions of the Mexican states of Sonora and Baja California stretching south to the upper Gulf of California. The delta once received all of the ~15 million acre-feet of annual water flow from the United States. Now only ten percent of that flows across the border, all of which is consumed by municipal, industrial, or agricultural users in Mexico. The only water that now regularly reaches the delta region comes from agricultural wastewater.

The delta ecosystem once occupied more than 2 million acres (3325 square miles) (Sykes, 1937), but has been reduced by more than ninety percent over the past 80 years. Much of the delta habitat that now exists lies just along the river's main channel, or in areas fed by agricultural wastewater drainage. Before the dams were built on the Colorado River the 3325 square mile (8612 square kilometers) delta region was a morass of twisting river channels, marshes, and jungle-like riverside forest vegetation.

The delta's marshes were once a primary stopover habitat for millions of birds migrating on the Pacific Flyway. Today the decline in wetland habitat has forced many migratory birds to use alternative water sources, including agricultural waste ponds and the Salton Sea, that favor the spread of avian disease and result in increased bird mortality. Several endangered species including the jaguar, desert pupfish, Yuma clapper rail, have also been adversely affected by the decline of the delta ecosystem.

Before the dams so much fresh water flowed down the river that the tidal estuary extended an estimated 25 miles (40 km) into the northern Gulf of California. The marine environment of the Gulf of California achieved its uniqueness in part as a result of the freshwater inflows from the Colorado River delta. With those flows gone, the estuarine environment is becoming increasingly saline, threatening many of the species that inhabit the gulf region including the endangered totoaba, a large relative of the white sea bass, and the vaquita harbor porpoise, one of the rarest mammals in the world.

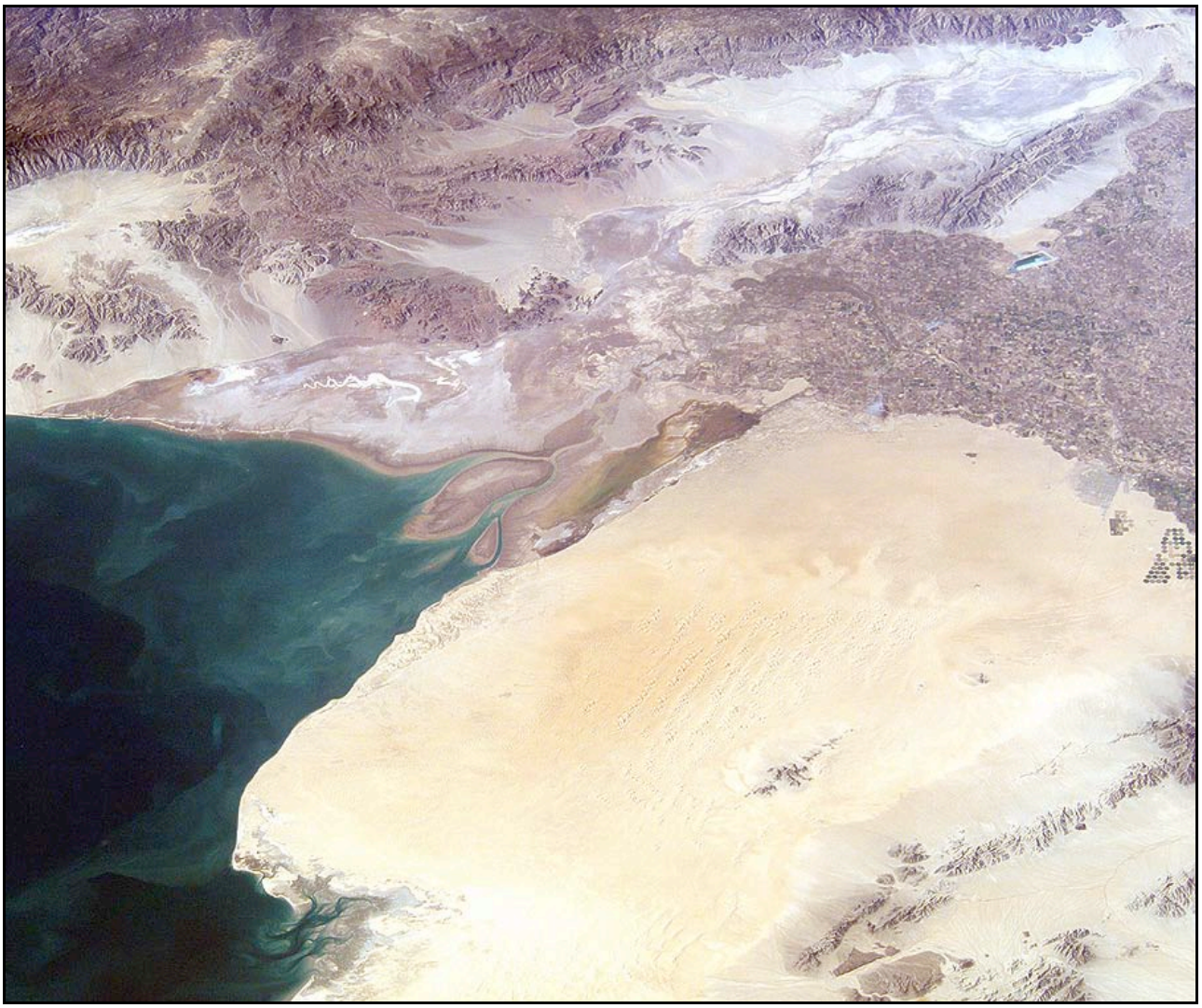
Web References

http://www.sci.sdsu.edu/salton/DecidingAboutCoR%20Delta.html

http://earthobservatory.nasa.gov/IOTD/view.php?id=4610

**The Colorado River from Yuma, Arizona (lower right)
to the Gulf of California**

(**June 28, 2001**, International Space Station (ISS) image courtesy of NASA)

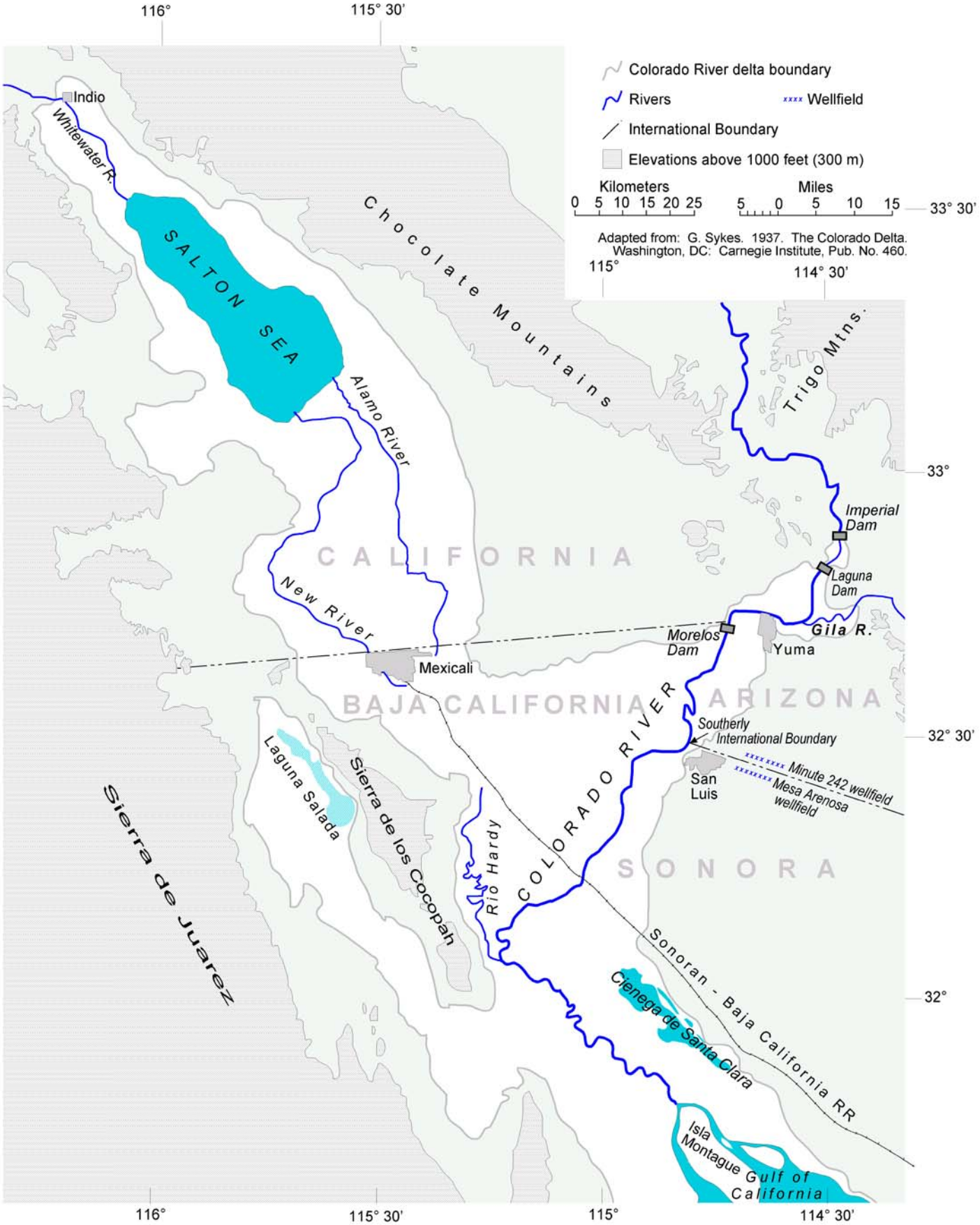


The Colorado River Delta

The Colorado River empties into the Gulf of California at the northernmost point of the gulf. The area is extremely hot and arid with average monthly temperatures in the summer exceeding 90°F (32°C), and average annual rainfall amounts of 2.4 inches (60 mm) making it the driest region in North America. The large island in the middle of the river's mouth (above just left of center) is Isla Montague. Its long axis is about 20 miles (32 km) in length. Isla Montague is approximately 65 miles (105 km) due south of Yuma, Arizona.

(**December 12, 2002**, ISS image courtesy of NASA)

The Colorado River Delta Region



Not more than 80 years ago the Colorado River flowed unhindered from northern Colorado through Utah, the Grand Canyon, Arizona, and Mexico before pouring out into the Gulf of California. But, as seen in this image of the Colorado River delta taken **September 8, 2000**, by the ASTER instrument aboard NASA's Terra satellite, irrigation and urban sprawl now prevent the river from reaching the gulf which can be seen in solid blue at the lower right hand corner of the image.

The Colorado River comes to an end just south of the multicolored patchwork of farmlands in the top left corner of the image and then fans out at the base of the Sierra de Mayor mountains (left edge center). A hundred years ago the river would have cut through this entire picture and plowed straight through to the Gulf of California. Today nearly all the water that flows into the Colorado is siphoned off to irrigate crops or for residential use.

The bluish purple river that appears to be flowing from the Gulf of California to the north is actually an inlet that formed in the bed of the Colorado River after it receded. The gray areas surrounding this inlet and the gulf itself are mud flats created by sediments once carried by the river. Dams now trap most of the river's sediments long before they find their way to the gulf.

The flat yellow expanse in the upper right corner is the Gran Desierto del Altar. Between the farmland and the desert is a dark blue pool covered with patches of green. Known as the Cièenega de Santa Clara (cièenaga means wetland in Spanish), it is a saltwater marsh formed by irrigation wastewater. The white patches to the southeast of this swampy area are barren salt flats that separate the marsh from the Gulf of California.

Change began to occur for the delta during the latter part of the 19th century. Ships traveling north from the Gulf of California would transfer their cargo to river steamboats, such as shown above, that supplied U.S. Army outposts and mining camps along the lower Colorado River. The steamboats were fueled by cottonwood from riverside forests. By the turn of the century hunters and sport fishermen from north of the border were partaking of the delta's bounty. Fishing villages developed on the upper gulf to supply Los Angeles and San Diego with shrimp, shark, turtle, and totoaba.

Above is an early example of sport fishing for totoaba in the upper Gulf of California. These fish grew to well over 200 pounds in weight, and there are records of some that approached 300 pounds. The totoaba migrate from the upper Gulf of California to spawn in the brackish waters of the estuaries of the Colorado River delta.

Photograph courtesy of Tony Reyes
http://www.sanfelipe.com.mx/business/tony_reyes/index.html

The giant totoaba once swarmed the northern Sea of Cortez in schools so thick they could literally be harpooned with one's eyes held shut. Beginning about 1920, the totoaba were caught by Mexican fishermen using only handlines, and the stocks were not appreciably depleted. In the early years, most of the fish were taken solely for their air bladders, which were dried and sold for use in a Chinese soup that was known as *seen kow*. The carcasses of the enormous totoaba were left on the beaches to rot.

Then, traders began buying the fish for as little as five cents each, and transporting them to the U.S. By 1942, over four million pounds of totoaba were exported to the Southern California wholesale market, and still the fish resisted the pressure successfully. But in the 1950s, dynamite and gill nets were used to intercept the totoaba before they could spawn in the estuaries of the Colorado River, and they became almost extinct within a few years.

(Photograph courtesy of Tony Reyes)

Web References

http://www.bajadestinations.com/afish/afish2001/afish011126/afish011126.htm

http://bajadestinations.com/afish/afish2003/afish030714/afish030714.htm

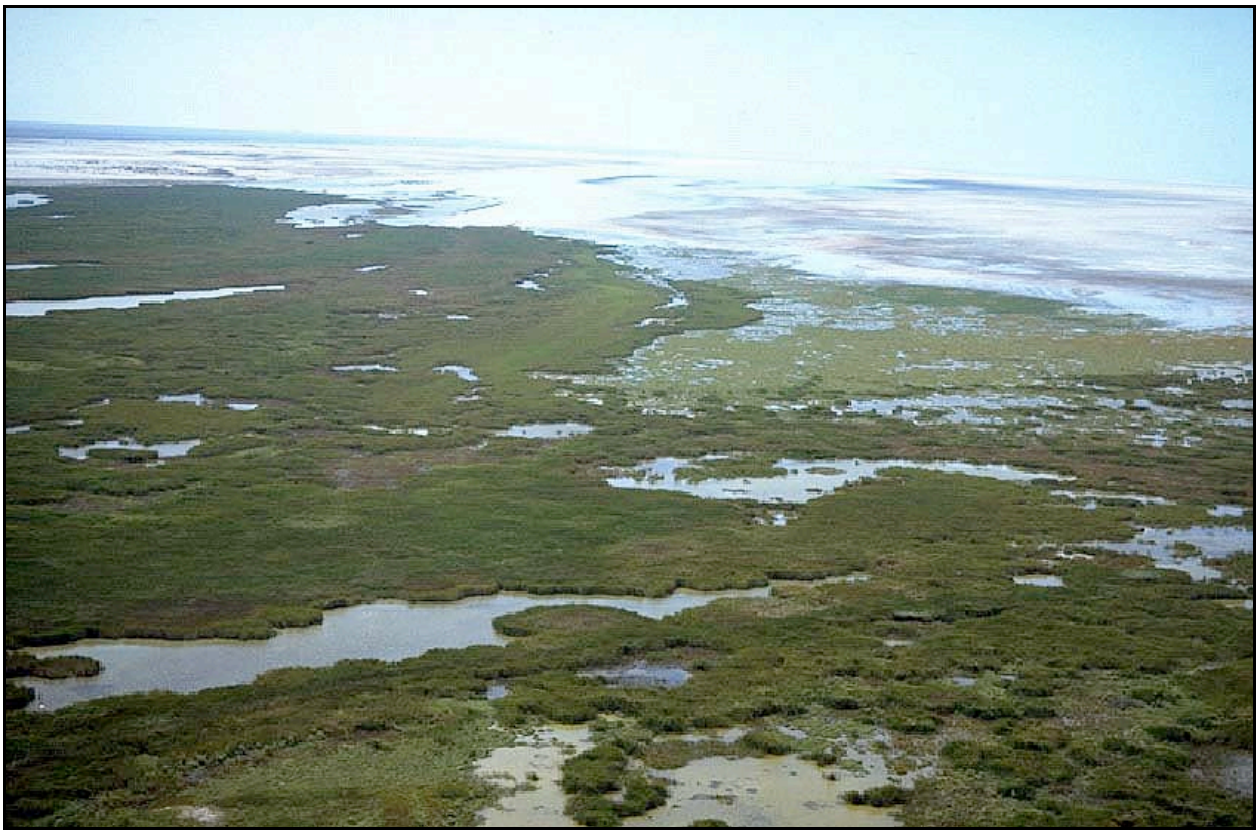
The Mouth of the Colorado River June 28, 2001

The dark area above left is the saltwater marsh the Cièenega de Santa Clara. It is home to perhaps the largest remaining populations of the Yuma clapper rails and desert pupfish, and is a major stopover for migratory waterfowl on the Pacific Flyway.

(ISS image courtesy of NASA)

The Ciènega de Santa Clara (shown above) covers approximately 15,000 acres of salt marsh and cattails. This image was taken **May 17, 2002**.

(ISS image courtesy of NASA)



The Ciènega de Santa Clara consists of extensive beds of southern cattails, interspersed with open water. The southern cattail is stress deciduous and goes through an annual cycle in the marsh of growth and regeneration followed by drying and browning. This undated photograph of the marsh is from the **January 2005** issue of the *Sonoran Joint Venture E-Bulletin*. The view is south toward the mouth of the delta. Note the white salt flats running from the edge of the green marsh to the gulf in the upper portion of this image.

Web Reference
http://www.sonoranjv.org/index.html

The image above shows the cattail beds during their cycle of drying and browning. This undated file photograph of the marsh by Peggy Peattie is from the **June 26, 2006**, issue of the *San Diego Union-Tribune* online.

In April of 2006, based on NASA satellite imagery, the Cièenega de Santa Clara suffered a major fire burning a large portion of the cattail beds of the marsh.

Web Reference
http://www.signonsandiego.com/news/mexico/20060626-9999-1n26delta.html

April 23, 2006, 1850 UTC
MODIS/Terra image

April 23, 2006, 2025 UTC
MODIS/Aqua image

Based on these two images, the fire was either not visible, or started after 1850 UTC, April the 23rd. At 2025 UTC, note the appearance of the gray patch at the north end of the marsh, which may be smoke.

April 24, 2006, 1755 UTC
MODIS/Terra image

April 24, 2006, 2105 UTC
MODIS/Aqua image

By 1755 UTC on the 24th smoke obscures most of the marsh. By 2105 UTC the MODIS instrument detected two fires in the marsh (red boxes) and a large plume of smoke drifting eastward.

April 25, 2006
MODIS/Terra image

July 6, 2006
MODIS/Aqua image

The image above, from April 25th, captured approximately 48 hours after the first indication of fire, shows much of the marsh may have been blackened by the fire. The second image shows the marsh almost ten weeks later. The Cièenega de Santa Clara appears reduced in size, but may be showing signs of green regeneration.

The April 23 to July 6, 2006, MODIS images are courtesy of NASA's MODIS Rapid Response System, AERONET La Jolla Subset. All of these images are 250 meters per pixel resolution.

Web Reference
http://rapidfire.sci.gsfc.nasa.gov/subsets/?AERONET_La_Jolla/

The 59 mile long Main Outlet Drain Extension (MODE)

The Wellton-Mohawk Irrigation District (WMID) in southwestern Arizona was established in the 1950s. WMID diverts approximately 400,000 acre-feet of Colorado River water annually to irrigate crops. Already salty Colorado River water, combined with the saline soil of WMID farmlands, creates a saline groundwater supply. As the underlying groundwater basin fills with water from the irrigated fields, salts are pushed to the surface. To keep the salts below the root zone, pumps remove about 130,000 acre-feet of brackish groundwater annually.

In the 1960s, Arizona began pumping this highly saline discharge back into the Colorado River at a point below the last dam in the U.S. but before the river reached the Mexican border. The United States was then able to deliver to Mexico the quantity of water established by treaty, while ignoring the fact that it was delivering highly saline wastewater instead of freshwater. Tensions over the salinity of the water allotted to Mexico escalated to crisis proportions in the 1970s, when Mexico lodged a formal complaint with the United States regarding the crop-killing salt water it was receiving. The ultimate solution was construction of a multimillion dollar desalination plant at Yuma, which, once it was up and running, would remove the salt from the Wellton-Mohawk wastewater before delivery to Mexico.

The Cièнega de Santa Clara (undated photograph)

In the interim, the offending irrigation drainage was rerouted away from the lower Colorado River by a 59 mile (95 km) long concrete canal running to the Cièнega de Santa Clara. Since its completion in 1965, the MODE canal has carried ~130,000 acre-feet of wastewater annually to the marsh.

Forty years later in 2005, the plant, completed in 1992 after almost 20 years of construction, was still off-line, but the continuous rerouting of Wellton-Mohawk irrigation wastewater had the accidental (but beneficial) side-effect of reviving the Cièнega de Santa Clara—one of the most important desert wetlands in the U.S. Southwest or Northern Mexico—from its low point of 500 acres to more than 15,000 acres currently.

Web Reference
http://www.coastalconservancy.ca.gov/coast&ocean/winter2002/pages/six.htm

Excerpts from **Climate Studies Hold Key to Future of Desalination Plant**

Paleontologists and hydrologists are being called in to help the US government decide what to do with a disused, $400-million desalination plant on the banks of the Colorado River. The researchers will study tree rings and clam shells, among other things, in a bid to establish long-term historical climate patterns in the river basin. These will help the US Bureau of Reclamation to determine whether it is worth reopening the Yuma Desalting Plant, which was designed to remove salt from the river before it reaches Mexico.

The plant was completed in Arizona in 1989, after salty water from the Colorado River had upset agricultural and natural ecosystems in Mexico. The salty water had entered the river from irrigation run-off from agricultural fields, particularly in western Arizona [the Wellton-Mohawk irrigation wastewater]. Other steps taken to address the problem included building a canal [the MODE channel] to divert agricultural run-off to a marsh near the Gulf of California [the Ciènega de Santa Clara].

The desalination plant was operated for a test period of about six months in 1992. But in January 1993, heavy rains diluted the river, making desalination operations unnecessary. The plant was subsequently criticized in media reports as a waste of taxpayers' money, and environmental groups complained about the potential impact of brine extracted by the plant that was sent to the Mexican marshland.

But a four-year drought in Arizona has led officials to try to find new ways of securing more usable water, while meeting the requirements of the complex laws and treaties covering the river. A treaty signed in 1944 requires the United States to send 1.85 billion cubic metres of water to Mexico via the river, with the salinity level not exceeding set limits. The desalination plant could make a partial contribution to this target by removing salt from part of the river's water flow—it can desalinate 92.5 million cubic metres of water per year.

Reopening the plant would cost about $25 million, and annual operating costs are also about $25 million, so bureau officials only want to do this if it will be needed for a sustained period. In January, they convened a group of researchers at the University of Arizona in Tucson to develop a model for predicting droughts and higher-precipitation periods for the next 50 years.

If the scientific studies show that it would be cost-effective to reopen the desalination plant, bureau officials expect such a move to face legal challenges from environmental groups. Just keeping the facility on stand-by costs about $3 million a year. (Dalton, 2003)

Explanation: The pressure to wring every drop possible from the Colorado River is increasing. Putting the Yuma desalination plant in operation would mean adding 75,000 acre-feet (92.5 million cubic metres) of freshwater per year that would be available for use in Arizona. This would cost $25 million per year and represent a direct subsidy from the federal government. That same water is currently going to the Ciènega de Santa Clara. The present situation gives Mexico 1.5 million acre-feet (1.85 billion cubic metres) per year of freshwater from the Imperial Dam *and* 130,000 acre-feet of Wellton-Mohawk irrigation wastewater from Arizona that now maintains the vitality of the Ciènega de Santa Clara. If the desalination plant starts up, the annual 130,000 acre-feet of brackish Wellton-Mohawk irrigation wastewater flowing to the marsh would be replaced by 55,000 acre-feet of extremely saline brine. This could mean the destruction of the Ciènega de Santa Clara marsh habitat.

And the news from the scientists is not good.

"Preliminary results suggest that the historical record of flow is not typical of long-term variation and that the southwest is in general drier than the past century has been." "What this is telling us is that on average, the historical record, the last 100 years in the Southwest United States has been on the really wet side. This is a conclusion that other paleoclimatologists, tree ring scientists and so on have already suggested on the basis of much shorter records. And what we're doing is we pushed this back to the 2,000 year mark now and we're tending to agree with them. So, basically our historical record, which is a record upon which we base all of our plans for development of the Southwest, our international agreements about how much water we keep in the United States and how much water goes to Mexico, is based on a biased sample of the distribution of flows from the Colorado River or a biased sample of the distribution of precipitation in the Southwest."

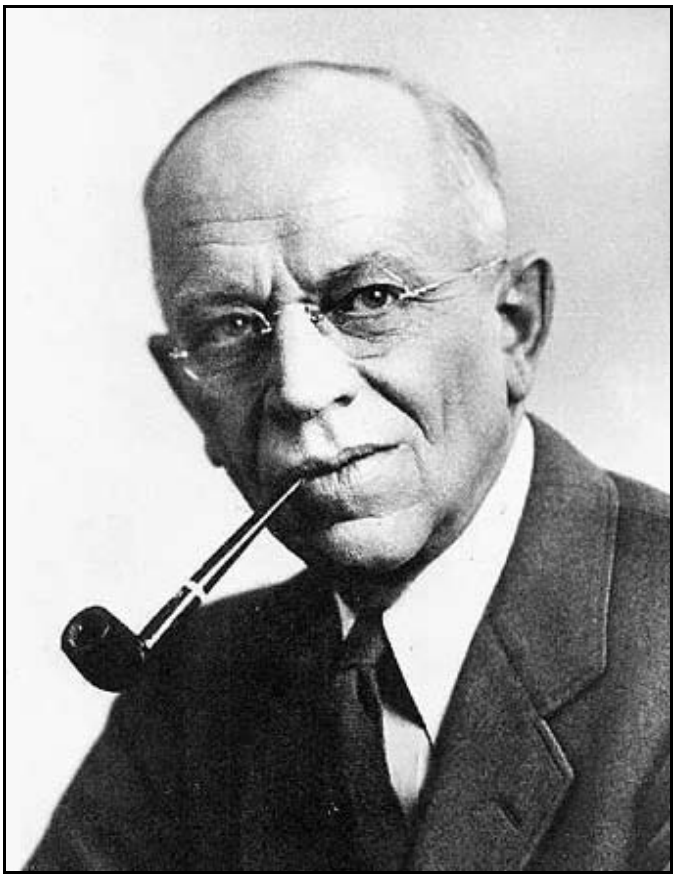
Dr. Peter D. Roopnarine, Asst. Curator, Department of Invertebrate Zoology & Geology, California Academy of Science, from *The Silence of the Clams* available at:
http://www.accessexcellence.org/BF/bf06/roopnarine/toc.html

What this means, if the scientists are correct, is that over the long term the operation of the Yuma desalination plant will be needed just to maintain current levels of freshwater use and thus may spell the end of the Ciènega de Santa Clara.

Bureau of Reclamation Desalting Plant in Yuma, AZ

In 2007, federal officials restarted the idled Yuma desalination plant. The Ciènega de Santa Clara marsh had been under continuous threat as U.S. water managers kept an eye on the flow to the ciènaga. The desalination facility in Yuma was opened in 1992, by the U.S. Bureau of Reclamation to treat saline wastewater, but costs were prohibitive and the plant has been closed since 1993. Drought has changed all that. Arizona water managers, who are first in line to have their water cut in a shortage under an agreement with other states, called for the plant to be turned on.

Under an agreement with environmentalists, the federal Bureau of Reclamation plans to monitor the environmental effects of using the plant, and study, among other things, using the purified water for purposes other than meeting its treaty obligations, such as supplying the growing communities around Yuma. (Archibold & Johnson, 2007, April 4)



Aldo Leopold (1887-1948)

The Green Lagoons

Before the dams were built, the Colorado River delta extended over two million acres, an area almost the size of Rhode Island, rich with nutrients brought downriver with tons of silt. In 1922, the conservationist Aldo Leopold and his brother explored the Colorado River delta by canoe. Leopold exulted in "all the wealth of fowl and fish…in this milk-and-honey wilderness" as his canoe wove through winding waterways and green lagoons. The two subsisted on quail and geese they harvested. Beaver, deer, and jaguar flourished, while shrimp and the totoaba, migrated from the upper Gulf of California to spawn in the delta's brackish waters. Millions of waterfowl and shorebirds could be seen circling, then descending to feed and rest in the lagoons. Leopold's essay *The Green Lagoons* in his book *A Sand County Almanac* (1949), gives a description of the delta as it was then. The following excerpts from the essay give a feeling for what has been lost.

Web References

http://www.naturespeace.org/geographygreaterla.htm

http://www.geocities.com/Yosemite/Gorge/5604/aldoleopoldcoloradodelta1.htm

(Painting of an Egret by Ray Harris-Ching)

"Dawn on the delta was whistled in by Gambel quail, which roosted in the mesquites overhanging camp. When the sun peeped over the Sierra Madre, it slanted across a hundred miles of lovely desolation, a vast flat bowl of wilderness rimmed by jagged peaks. On the map the delta was bisected by the river, but in fact the river was nowhere and everywhere, for he could not decide which of a hundred green lagoons offered the most pleasant and least speedy path to the gulf. So he traveled them all, and so did we. He divided and rejoined, he twisted and turned, he meandered in awesome jungles, he all but ran in circles, he dallied with lovely groves, he got lost and was glad of it, and so were we."

"The still waters were of a deep emerald hue, colored by algae, I suppose, but no less green for all that. At each bend we saw egrets standing in the pools ahead, each white statue matched by its white reflection."

References

Archibold, R. C. & Johnson, K. (2007, April 4). An Arid West No Longer Waits for Rain. *The New York Times*, U.S..

Dalton, R. (2003). Climate Studies Hold Key to Future of Desalination Plant. *Nature*, 422 (March 6), 4-5.

Sykes, G., 1937. The Colorado River Delta. *American Geographical Society Special Publication*, no. 19, American Geographical Society, New York, New York

For further information on the delta of the Colorado River see:

Missing Water by the Pacific Institute
http://www.pacinst.org/reports/missing_water/

Since the dams: Historical Ecology of the Colorado Delta
http://www.geo.arizona.edu/ceam/Hecold/hecolcd.htm

Dead Delta's Former Productivity
http://www.geol.vt.edu/paleo/g281059.pdf

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