The River, the Delta, and the Sea

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> The remnants of the ship-yard interested us so much that we made the slough our headquarters for some days while we explored the estuary and our other surroundings, and my partner, who was an inveterate fisherman, found that the waters thereabouts were infested by great numbers of large, unattractive-looking fish, which appeared to be attracted by bacon-rind and other food-scraps, so he spent much time catching far more than we had any possible use for and no more Indians turned up to whom we might give them. Their flesh was toothsome and satisfying, but they were unpleasant to look upon and appeared to be dull and unintelligent.
>
> —Godfrey Sykes, *A Westerly Trend,* 1945

Godfrey Sykes, in his memoir, recalls how he and an ex–cattle thief-whaler-boatman set out to explore the lower Colorado River and the Gulf of California, and then the South American coast in the winter of 1890–1891. Their voyage ended abruptly in a lagoon four days walk south of San Felipe Point when Sykes, lighting a cranky kerosene lantern, accidentally burned his boat. Sykes had built the craft at his home in Flagstaff, shipped it by flatcar to Needles, launched it, and learned some rudimentary navigational skills from the legendary riverman Captain Jack Mellon. He commenced to discover what was to become his enduring passion, the Colorado Delta. The transplanted Englishman would return to the delta frequently, in the employ of Carnegie Institution's Desert Botanical Laboratory. Sykes worked out of the Tumamoc Hill facility in Tucson from 1906 to 1929. *The Colorado Delta* (1937), Sykes' hydrological, historical, and sociological treatise, summed a career of careful observation.

That first ill-fated excursion would end on foot as Sykes and the anonymous cow rustler hiked back to civilization—Yuma—with a recu-

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perative stop at the tepid waterhole near San Felipe Point. When the two reached Yuma, they witnessed the aftermath of a devastating flood on the Gila-Colorado system in early February:

> The place was almost unrecognizable. The main, and only, street was a muddy gully, adobe and willow-pole houses, stores and saloons were mostly heaps of ruin and the inhabitants were either grubbing about in the piles of débris in search of treasured belongings or sitting perched upon the higher heaps, considering matters. (Sykes [1945] 1984: 224)

Had those floodwaters reached the Gulf, Sykes' delta exploration might have been more adventuresome. As it was, the water drained into the Salton Sink. Sykes—with a new boat and a new partner, "Beer-keg Tex"—set off immediately to trace its northwesterly course.

The chronology would have likely placed Sykes and his previous partner at the abandoned shipyard of Port Isabel sometime in January. The *totoaba,* believed historically to spawn in mass schools in the shallow, brackish waters of the Colorado Delta, may have been the fish that the partner overexploited. Several decades later, this fish would attract fishermen, traders, and settlers to the upper Gulf of California—to the waterhole near San Felipe Point, to El Golfo de Santa Clara near the abandoned Puerto Isabel (see Sykes 1976), and to the sheltered harbor of Puerto Peñasco. In subsequent years, shrimp displaced totoaba as the dominant commercial species in the region—due in part to the drastic decline in totoaba stocks, a fatal flaw of their mass spawning behavior, which Sykes' cow-thief partner was probably exploiting.

A century later, the region and the species received some remedial attention. A presidential decree established the Reserva de la Biósfera Alto Golfo de California y Delta del Río Colorado on 11 June 1993. The primary objectives of the reserve are (1) to conserve the ecosystems of the Sonoran Desert, the upper Gulf of California, and the delta of the Río Colorado; (2) to grant permanent protection to unique and endangered species such as the totoaba, the vaquita, the desert pupfish, and various bird species of the delta's wetlands; (3) to regulate productive activities to safeguard natural resources; (4) to promote alternative economic activities that will raise the quality of life of inhabitants; and (5) to assist in the recovery and preservation of flora and fauna in the region.

Rejuvenating the flora and fauna of the Colorado River Delta has become a *cause célèbre* among conservation groups. American Rivers lists that reach of the river as its sixth most endangered (American Rivers 1998). Defenders of Wildlife has sued to extend the mandate of the U.S. Fish and Wildlife Service's Lower Colorado River Multi-Species Conservation Plan into Mexico's delta (Fritschie and Miller 1997; Glennon and Culp 2002). Tucson's Sonoran Institute has reported to Defenders and to the National Park Service on the "opportunities for ecological improvement" along the lower river and its delta (Briggs and Cornelius 1997) and has taken a lead role in further assessments of ecosystem restoration. The Environmental Defense Fund has issued an action plan: *A Delta Once More: Restoring Riparian and Wetland Habitat in the Colorado River Delta* (Luecke et al. 1999). The Pacific Institute for Studies in Development, Environment, and Security produced a similar assessment of needs for the delta (Morrison, Postel, and Gleick 1996) and proposed an environmentally friendly river management scheme to the U.S. Department of the Interior and its river operator, the Bureau of Reclamation. That proposal was cosigned by American Rivers, Defenders of Wildlife, the Environmental Defense Fund, Friends of Arizona Rivers, the Sierra Club, the Sonoran Institute, and others (Pacific Institute 2000; cf. Pitt et al. 2000).

The common thread in these propositions is the linkage of the river, the delta, and the sea: the need to find spare water somewhere along the basin of the river, flow it through the delta to restore wetlands habitat and its endangered fauna, and pass that water into the gulf to enhance the aquatic ecosystem. This linkage is engrained in the epistemology of fishermen in the upper gulf as well. They insist that once the river was fully and finally dammed, little freshwater has reached the sea, the nursery grounds of the estuary have been impoverished, and their stocks of fish and crustaceans have been diminished (see McGuire and Greenberg 1993).

The initial proposal to restore the gulf's aquatic system, and perhaps its fishery, appeared in 1994 in the *Colorado Journal of International Law and Policy*. It was predicated on the linkage of the river, the delta, and the sea. Like the subsequent lawsuit brought by Defenders of Wildlife, this plan contends that the Endangered Species Act has international reach. I will return to the proposal's law and policy below, but Frank Wilson argued that "the United States and Mexico should enter into an agreement whereby the United States would, as possible, increase its delivery of water to Mexico. Mexico would agree to leave the excess water in the river and would reap the benefits of a functional brackish estuary" (Wilson 1994: 258).

The immediate beneficiaries of this proposal to restore a functional estuary, Wilson believes, would be the totoaba and the vaquita. Totoaba (*Totoaba macdonaldi*) is a croaker that grows up to six feet long and three hundred pounds. It was exploited originally for its air bladder, exported to the Orient for use in soups. The carcasses were left to rot on the beach (Chute 1928; Craig 1926). After 1920, however, it became a highly prized commercial and sport fish, the most valuable resource until commercial shrimp trawling developed on a significant scale in the 1950s and 1960s. Totoaba spawns at the mouth of the Colorado River, and a sanctuary was established there in 1955. In 1975, following drastic declines in totoaba stocks, commercial and sport fishing for the species was outlawed (Flanagan and Hendrickson 1976). Nevertheless, totoaba gillnetting continued until very recently and was a primary cause of incidental kills of the vaquita (*Phocoena sinus*), a small porpoise endemic to the upper gulf and acknowledged by the Scientific Committee of the International Whaling Commission as the most endangered cetacean in the world. Both of these endangered species, endemic to the upper gulf, encounter the estuarine waters of the delta during portions of their life cycles.

The linkage of the river, the delta, and the sea makes consummate sense logically and, perhaps, ecologically. However, I will build an argument for disentangling them, and for addressing the problems of each on its own terms.

The Pacific Institute's proposal to the Bureau of Reclamation is based on research that implicitly severed the delta from the sea. It calls for an annual flow of 32,000 acre-feet, an estimate deemed adequate to "maintain, even improve, cottonwood-willow habitat in the upper reaches of the Delta" (Pitt et al. 2000: 831). A pulse flow of 260,000 acre-feet every four years or so would "inundate the Delta's floodplain within the levees, sustain riparian corridor vegetation, and stimulate seed germination" (Pitt et al. 2000: 831). The stakeholders marshaled in support of the proposal are all from the delta; the anticipations of fishermen in the upper gulf are deflected to a footnote: "[F]reshwater flow needs of Delta fisheries and Gulf near-shore marine species have not been quantified. The flows needed for restoration cited in this article do not include the needs of aquatic species" (Pitt et al. 2000: 831).

I will review the needs of those aquatic species in some detail, as well as the natural and institutional history of the delta and the river. Not surprisingly, there is institutional resistance to treating the river, the delta, and the upper Gulf of California as a single ecosystem. Of more interest is the evidence that the delta and the sea may now be largely discrete entities ecologically, and that the solution to the problems of each may not lie simply and solely in the river.

The Colorado is the archetype of an over-appropriated river. Nonetheless, there is water that is not now being put to consumptive and profitable use, and this has fueled the proposals to restore flows through the delta. Over the last decades, for example, Indian reservations in the West have won entitlements to large quantities of water, sufficient under long-standing legal doctrines to irrigate all "practicably irrigable acres" of reservation lands. Those reservations are now balking at such landscape-altering plans (see McGuire 1991a; McGuire, Lord, and Wallace 1993). Farmers are now resolutely following the predictions of economists thirty years ago that they would reduce their water usage as the costs of extracting groundwater from an ever-deeper aquifer increase (Kelso, Martin, and Mack 1973). Fostered by institutional arrangements to allow the transfer of such saved water to municipalities, this practice has the potential of substantially reducing the cities' demands on the stored surface flow of the region's rivers (see Western Water Policy Review Advisory Commission 1998).

Water flowing through the 355-mile canal of the Central Arizona Project (CAP) to its terminus at Tucson has been underutilized. That city's water customers rejected this imported river water in the 1990s, forcing the municipal water utility to concoct a non-corrosive blend of groundwater and canal water. Irrigation districts were designated in the early plans for the CAP as the primary beneficiaries of imported water. When that water was priced substantially higher than existing groundwater, they faced bond defaults and bankruptcies as they struggled to pay the costs. Agricultural economist Paul Wilson calculated that agricultural purchases of CAP allocations declined 50 percent in the early years of the canal's operation (1989 to 1991) and predicted that this would be a long-term trend (Glennon 1995; Wilson 1992).

But the slack in the system is ever tightening as institutional arrangements are fine-tuned. Unused allocations of river water can now be banked in underground aquifers for future withdrawal. The Arizona Water Bank is a peculiar institution, created by the state legislature in

1996 as a means of storing an unused allocation of CAP water (LaBianca 1998). That unused allocation had historically been diverted to southern California, so the creation of the bank put intense pressure on California to live within its legal limit of 4.4 million acre-feet (maf) of Colorado River water, as established by the U.S. Supreme Court in 1963. By 1999 the major water users devised a complex plan, the Quantification Settlement Agreement (QSA) whereby water would be transferred from two irrigation districts, the Imperial and the Coachella Valley, to two cities, Los Angeles and San Diego. Under the agreement, California would gradually reduce its take from the river to its proper 4.4 maf after 2015. To get to that point, California wanted and got a concession from the federal government, a "soft landing." The Bureau of Reclamation revised its Colorado River Surplus Criteria to allow drawdowns of its main storage reservoirs, Lake Mead and Lake Powell, to assuage California's belt-tightening process. These reservoirs would then have the additional capacity to capture and hold what had previously been "surplus" water occurring during years of high precipitation and snowpack. With some frequency in the 1990s, this surplus had been allowed to spill into Mexico, in addition to that country's 1944 treaty rights to 1.5 maf annually from the river (Glennon and Culp 2002).

California's QSA was contingent on Reclamation's altered river management, and the Interim Surplus Criteria were contingent on the QSA. Interior Department Secretary Bruce Babbitt signed the government's concession a day or two before leaving office, but the Imperial Irrigation District subsequently reneged on the QSA. Babbitt's successor, Gale Norton, retaliated by cutting back the irrigation district's water allocation for 2003 and the district brought suit against her (Imperial Irrigation District 2003a, 2003b). She, in turn, dissolved the Interim Surplus Criteria. Spokesmen for the profligate Metropolitan Water District (MWD) of southern California were nonetheless upbeat:

> Although the immediate cutoff of surplus Colorado River water supplies due to the federal government's suspension of the Interim Surplus Guidelines presents a serious situation for the state, there clearly is no emergency in urban Southern California because of the planning and foresight of Metropolitan and its 26 member public agencies. (Metropolitan Water District 2003)

With sixteen million urban customers in need of water in southern California, it is inevitable that the Imperial Irrigation District will be pulled back on board for the relatively meager expense to MWD and others for upgrades in the district's inefficient irrigation works.

The Pacific Institute's proposal to assure surplus flows to the delta was developed as a response to the draft environmental impact assessment of the Interim Surplus Criteria. Secretary Babbitt, in a speech, had proclaimed that the surplus criteria should result in "no net loss" of environmental benefits, and the Pacific Institute endeavored to hold him to his word. In the Institute's alternative, reservoirs would be drawn down further to supply 32,000 acre-feet annually to the delta south of the international border. In flood years, it called for an additional 260,000 acre-feet of water across the border. These were estimates, based on observations in the delta during the 1990s of the annual and pulse flows needed to maintain and restore habitat. The Bureau of Reclamation rejected the Institute's proposed alternative, arguing that it did not have the "discretion" to deliver additional flows for habitat purposes. Mexico had such discretion, but Reclamation argued that country may choose not to let the flows reach the delta, diverting them instead to farms and cities below the border.

The Bureau of Reclamation had used a similar argument in developing its Lower Colorado Multi-Species Habitat Conservation Plan, whose scope terminated at the international line. As that plan was being developed, both the U.S. Fish and Wildlife Service and National Marine Fisheries Service issued initial opinions that the habitat of the delta and the marine mammals of the upper gulf should be incorporated into Reclamation's "action area." Then they retreated. Mitigation measures for endangered species in Mexico were not required because, "The United States, and therefore Reclamation, has no authority or discretion over the flow of water to the Colorado River delta as a result of the Mexican Water Treaty of 1944 and the 1964 Supreme Court decision that enjoined Reclamation from releasing excess water to Mexico beyond that called for in the Treaty" (*Defenders of Wildlife v. Norton* 2003: 13)

Courts and agencies in the United States are thus holding close to the Law of the River. Those who seek water for the delta and the sea will have to bend and amend the complex of regulations, compacts, and treaties that entangle the Colorado's current appropriators.

The Cucapá, original inhabitants of the delta, endeavored to plant and harvest on the rich soils of the deltaic fan, but their difficulties were daunting. Some years, adequate soaking floods failed to come. In other years, the peak summer floods would arrive and recede in time to allow an adequate planting, only to be followed by a second flood that scoured the fields again. And, as Sykes witnessed in 1891 (and a number of times thereafter) the flood overflow would refuse to behave, jumping ill-defined river channels to go elsewhere. Aldo Leopold remarked on this phenomenon while canoeing the delta with his brother in 1922:

> 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. For the last word in procrastination, go travel with a river reluctant to lose his freedom in the sea. (Leopold 1949: 141–42)

Unlike the Leopolds, the Indians were there to make a living, of sorts, and they coped. Ethnographer William H. Kelly has reconstructed their efforts from informants alive in the 1930s and 1940s. And he has arrayed some useful data on the natural river. On average (in fact the average from 1903 to 1934), the Colorado River and its tributaries delivered 15,298,200 acre-feet of water to, and past, Yuma, at the head of the delta. On average, 8,718,500 acre-feet of this flow came during the critical months of May, June, and July, when it would flood, soak, and enrich the fields along the river's many channels. But the Cucapá farmers had little faith in averages. As Kelly summarizes,

> If the flood was of such minor proportions that it did not reach a prepared plot, or if a shift in delta contour left a farm high and dry, a substitute plot was found whenever possible. If a second rise in flood water returned to a planted area and washed out the seed, or if the ground remained wet so long as to damage the seed, the plot had to be replanted, provided the season had not progressed too far. A high flood of any duration after the crops were well up was, of course, ruinous. (Kelly 1977: 26)

The Cucapá endeavored to handle the river's fickleness with dams, levees, and ditches. The simplest water system, resorted to in years when the river's floods were inadequate, involved a ditch cut into the banks of a slough to drain water onto the surrounding lower lands. More commonly, the Cucapá constructed dams near the source of major sloughs, directing water to adjacent farms. Or, as Kelly (1977: 27) observes, "Along smaller sloughs the water was spread out over the land by building a series of earth dams across the slough. When the rising water had backed up behind the first dam and had spread over the land, this dam was cut and the water permitted to reach the second dam, to spread again from that point." More ambitious, though less common, was the practice of constructing high earthen levees between the fields and the sides of the rivers or sloughs. These levees would be breached to admit the first flood waters and saturate the ground, and then closed. The same structures would serve as protection from any subsequent river crests during the growing season.

The quality of the delta for farming was by no means uniform. Soils differed, floods were not spatially uniform, and natural vegetative cover made some areas difficult to prepare for planting. As Sam Spa instructed the ethnographer Kelly (1977: 28), "Stay away from low, spreading weeds and grass and look for a place where quelite, arrowweed or willow seedlings come up thick. Sometimes we planted just a little here and there and then we came back and planted more where the corn shoots looked best." Indeed, the worst spots for farming were those where Leopold's river took "the most pleasant and least speedy path to the Gulf," since the fine silts deposited there formed heavy soil, subject to frequent cracking and difficult to work (Kelly 1977: 28).

In the nineteenth century, Cucapá planted and harvested corn, tepary beans, pumpkins, watermelons, muskmelons, and cowpeas for food, and gourds for containers and rattles. All the crops were under constant assault from insects and animals. Rabbits and crows were particular nuisances, and boys would be dispatched with bows and arrows to protect the fields. Nevertheless, there were years when entire plantings might be destroyed by predators.

According to Sam Spa, harvest time was a season of "tremendous eating." But ethnographer Kelly remarks on a paradox of life and uncertainty on the delta:

> From the point of view of their natural environment and their technology, the Cocopa of the 19th century should have been well fed and prosperous, but they were not. The facts on subsistence reveal chronic short rations during the late spring and early summer, and near-famine conditions in some years when the summer floods failed. (Kelly 1977: 23)

The wild rice harvest of mid-May relieved the hunger of the spring and brought Cucapá groups together at the estuary of the river for visiting, gambling, and singing. The halophyte could always be counted upon for it was dependant on the sea, not the river. Botanist Edward Palmer reported on this resource (*Uniola palmeri* Vasey) in the 1870s and 1880s:

> As its quantity depends on the overflow of the tides, and the tides are sure to occur, they have an assured crop without any other labor than gathering and caring for the grain. The gatherers enter the fields as the tides have entirely run off, where the soil is an adhesive clay so soft that the Indians often sink nearly to their knees in gathering the grass, and as soon as the tide begins to flow they return with the result of their labor to their camps. (Quoted in Kelly 1977: 35)

Mesquite and screwbean were the staples during the planting season, along with quelite, an amaranth which, as much as the domestic crops, was dependent on the annual river overflow. Cucapá also were reported to have planted and harvested two wild seeds, a panic grass and a crowfoot grass. Minor utilization of a number of other delta plants also occurred, including an abundant wild onion (*Sagittaria latifolia*) and the tule or cattail (*Typha latifolia*), the roots of which supplied a never-failing though unpopular food (Kelly 1977: 39).

Fish and wild game complemented each other in the seasonal round of subsistence for the Cucapá. The availability of fish diminished through late winter and spring, as the river went down, and this was when rabbits, quail, ducks, and other small game and birds were hunted with bow and arrow.

Interestingly, William Kelly presaged for the delta Cucapá a complaint heard from contemporary fishermen in the Sea of Cortez: that the fate of the fish is tied to the fate of the river:

> Early travelers always spoke of the great quantities of fish seen in Cocopa and other River Yuman camps. . . . During the time of

> our fieldwork, however, perhaps because of changed conditions on the river, fish were not an important source of food. Every Cocopa family in Mexico possessed fishing nets but used them only rarely. Only two of the poorest families, both living near water, usually had fish in camp when we visited them. (Kelly 1977: 44)

Within the biosphere reserve, modern Cucapá retain the right to fish the tamed channels of the delta, but not to hunt the remaining ciénegas. Aldo Leopold, an avid sportsman much of his life and better armed than the natives of the delta, availed himself of the still-abundant game in the wetlands of the 1920s:

> [W]e lay in wait beside an ordinary-looking slough, its bars covered with yesterday's goosetracks. We were already hungry, for it had been a long tramp from camp. My brother was eating a cold roast quail. The quail was halfway to his mouth when a cackle from the sky froze us to immobility. That quail hung in mid-air while the flock circled at leisure, debated, hesitated, and finally came in. That quail fell to the sand when the guns spoke, and all the geese we could eat lay kicking on the bar. (Leopold 1949: 145)

Leopold had already prefaced his essay on his visit to this "Green Lagoon" with a prescient thought: "It is the part of wisdom never to revisit a wilderness, for the more golden the lily, the more certain that someone has gilded it" (141).

Leopold took pleasure in the capacity of the delta to swallow up its river. This made for lush habitat and good hunting. In truth, the Colorado has, more often than not, gotten lost before reaching tidewater. The river began to disappear first through its own doing, then through human activity shortly after the turn of the century. In meticulous detail, Godfrey Sykes charted the course of this decline from a navigable stream in the nineteenth century to one in desperate search for an outlet to the gulf by the 1930s.

For two and a half decades, the 1850s to the middle of the 1870s, the lower river carried people and goods from California to the junction of the Gila and the Colorado, a trip under steam of two weeks. People and goods changed vessels at Puerto Isabel, the shipyard at the mouth of the estuary. From there, travel up the river was by shallow-draft sternwheelers, and it was not without peril. Sykes writes

> in an unmarked and rapidly changing channel situated in a practically unknown region, and upon a river which was subject to great and oftentimes sudden rises, any particular voyage might reasonably be anticipated to develop into an adventure or an exploration rather than into a mere commercial undertaking. It is not surprising, therefore, to learn of steamers and barges, especially when dropping downstream, occasionally blundering or being helplessly carried into openings in the always treacherous western bank in times of high water, and having funnel, pilot-houses, hog-posts, or other superstructures wrecked or carried away by falling or leaning trees, in swift narrow channels, before they could be brought under control or could work their way back into known parts of the main river. (Sykes 1937: 31)

Supplies for the military at Camp Yuma and for transients on their way to the goldfields of California were loaded on prosaically named barges—Nos. 1, 2, and 3 of the Colorado Steam Navigation Company—pulled by boats that were frequently refabricated from the salvaged parts of wrecked vessels—the *Cocopah* (Nos. 1 and 2), the *Colorado* (Nos. 1 and 2), the *Mojave* (Nos. 1 and 2), and the speedy and durable *Gila*, launched from Puerto Isabel in 1873. Boatmen developed their own peculiar strategies for navigating the delta:

> The tow was occasionally cast off while the steamer "backed-up" to an obstructing bar, to dig its way across by the use of the wheel. The wheel was also frequently used to throw water under the tow when it took the ground. Kedging or warping by means of trees and stumps ashore was at times necessary in making bends and crossings with a strong beam wind, as the barges generally exposed a high freeboard on a shallow draft and readily drifted to leeward. "Sounding" in difficult river stretches was usually done by an Indian stationed in the bow, by means of a long peeled willow pole which he alternately thrust down to the bottom and pulled up again in sight of the pilot. (Sykes 1937: 32)

The historic trade on the lower river ended through a very modern mechanism:

> Profitable transportation business between the sea and Yuma ceased in 1877, when the Southern Pacific track reached the Colorado. In order to avoid possible disastrous competition between the two services, the railroad company quickly acquired the rights,

> property, and good will of the river company, retaining the boats for such up-river business as might continue to be profitable. The shipyard at Puerto Isabel was dismantled early in 1878. Since the diversion of the river in 1909, no practicable channel even for the smallest craft has existed through the delta. (Sykes 1937: 34)

Sykes himself learned to navigate the river from Captain Jack Mellon of the *Cochan,* and his first truncated voyage in 1890 was followed by many more. From these, he reconstructed the river's history in its natural state, if there was one, and in its manipulated state. Perhaps better than Sykes himself, Engineer H. T. Cory characterized the problematic of that later state. There were "two serious problems: the danger of diverting water from a wide, erratic stream flowing through a shifting channel along the top of a ridge of loose alluvial silt; and the difficulty of keeping open canals which carried water so heavily charged with silt" (Cory 1913: 1246).

These problems were not problems until the years 1900 to 1910, which Sykes wryly labeled the "decade of the great diversion." The previous ten years were ones of "relative stability" on the delta.

The decade of the 1890s did not start out stable, however. The great flood in the winter of 1891, the devastation of which Sykes observed at Yuma when he returned on foot from his first exploration of the gulf, came from the Gila. Runoff through the delta went in two directions from the main channel, then closely skirting the mesa on the Sonoran side. Some water went into the Paredones drainage, then into Volcano Lake, then into the Hardy, ultimately flowing south to the gulf. The bulk of the water escaped into the Alamo channel, which flows northwestward, not south. Sykes procured a small skiff in Yuma to follow this flow through a sparsely inhabited region. His exploration—"a strenuous and somewhat hazardous voyage"—led him into the Salton Sink, the ancient lakebed some 280 feet below sea level in what was then known as the Colorado Desert, soon given the more alluring name of Imperial Valley.

For much of the balance of the decade, the river flowed with relative normality, cresting in summer, ebbing in winter. But Sykes was reaching a disturbing conclusion by the close of the century:

> [T]he final years of the nineteenth and the first five years of the twentieth century marked the culmination of a phase in the geomorphic development of the delta during which the river channel above the head of tidewater was gradually reaching the limit of its

> carrying capacity for suspended and saltatory material, prior to the inevitable serious breaching of one or both banks. (Sykes 1937: 46)

He thus commences his chapter on the period of the great diversion with the following summary:

> The opening decade of the twentieth century ultimately developed into the most important one in the recent history of the delta and especially of the Salton depression, although during its first quinquennium there was little apparent change in the river. The bed of the channel was undoubtedly steadily rising, and the building up of local accumulations of sedimentary matter became obvious from the increasing tendency of the river to enter and develop cut-offs and break across its banks at each period of high water. (Sykes 1937: 47)

Away from the river, schemers and settlers were beginning to lay claim to the Imperial Valley, drawn by the obvious conclusion from the 1891 episode that lands on both sides of the international line could be irrigated by gravity flow from the Colorado. The earliest of the visionary schemers was a Dr. Wozencraft who, viewing an identical overflow through the Alamo channel into the Salton Sink in 1849, repeatedly and unsuccessfully sought a grant from the U.S. Congress for six million acres of land between the river and California's Coast Range. A number of other propositions followed, and a Yuma boatman actually dug a ten-mile irrigation canal west from the river in 1857. Unfortunately, it ran upslope (Lingenfelter 1978: 135). Finally, in 1900, a California land promoter and engineer, George Chaffey, joined forces with irrigation engineer Charles Rockwood to bring Wozencraft's vision to fruition. They incorporated the California Development Company in New Jersey, established a Mexican company that was ceded 800,000 acres of land in the Mexicali Valley by Porfirio Díaz, and ran a diversion canal from bedrock near Pilot Knob, a mile into the United States, through Mexico, and into the channel of the Alamo River. The first irrigation water was delivered to the Imperial Valley north of the border in 1901. By 1902–1903 there already were 12,000 irrigators in the valley, who threatened to litigate the California Development Company when it failed to deliver the promised water due to a low river in 1902 and 1903.

The company settled out of court, and Charles Rockwood took measures to avoid a reoccurrence in the future. The problem he faced was the silt load from the slackened river, which clogged the first several miles of the canal from the Chaffey Gate at Pilot Knob. Dredging efforts failed, so in 1904 Rockwood sought a concession from the Díaz government to build a new cut to the Alamo on the Mexican side of the line. He completed the intake in the winter of 1904–1905, a simple cut through the mainstem's banks and levees, without a headgate. (The Mexican government was slow to grant the company permission for the structure, and anyway the company's finances had been seriously depleted by the court cases and settlements of the previous years.) This is Rockwood's own account of ensuing events, quoted in a paper by the engineer brought in to correct the disaster:

> *Unprecedented River Conditions.*—In the meantime serious trouble had begun. We have since been accused of gross negligence and criminal carelessness in making the cut, but I doubt as to whether any one should be accused of negligence or carelessness in failing to foresee that which had never happened before. We had before us, at the time, the history of the river as shown by the daily rod readings kept at Yuma for a period of twenty-seven years. In the twenty-seven years there had been but three winter floods. In no year of the twenty-seven had there been two winter floods. It was not probable, then, in the winter of 1905, that there would be any winter flood to enlarge the cut made by us, and without doubt, as it seemed to us, we would be able to close the cut before the approach of the summer flood by the same means that we had used in closing the cut for three successive years around the Chaffey gate at the head of the canal.
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> During this year of 1905, however, we had more than one winter flood. The first flood came, I believe, about the first of February, but did not enlarge the lower intake. On the contrary, it caused such a silt deposit in the lower intake that I found it necessary, after the flood had passed, to put the dredge through in order to deepen the channel sufficiently to allow water to come into the valley for the use of the people.
>
> This was followed shortly by another heavy flood that did not erode the banks of the intake, but, on the contrary, the same as the first, caused a deposit of silt and a necessary dredging. We were not alarmed by these floods, as it was still very early in the season. No damage had been done by them, and we still believed that there would be no difficulty whatever in closing the intake

> before the approach of the summer flood, which was the only one we feared. However, the first two floods were followed by a third, coming some time in March, and this was sufficient notice to us that we were up against a very unusual season, something unknown in the history of the river as far back as we were able to reach; and it was now approaching the season of the year when we might reasonably expect the river surface to remain at an elevation that would allow sufficient water for the uses of the valley to be gotten through the upper intake, we decided to close the lower.
>
> *Five Floods in One Season.*—Work was immediately begun upon a dam similar to the ones heretofore successfully used in closing the cut around the Chaffey gate. The dam was very nearly completed, when a fourth flood coming down river swept it out. Work was immediately begun on another dam which was swept away by the fifth flood coming down during this winter season. (Quoted in Cory 1914: 1287–88)

Engineer H. T. Cory describes one of many proposed solutions to the runaway river, then flowing freely into Salton Sea:

> The Barrier Dam Plan consisted in throwing a barrier dam of some sort across the crevasse and raising the water surface above it sufficiently high to throw all the discharge of the river down the old channel to the Gulf. . . . This method seemed to its proponents to afford opportunity for decreasing the quantity of water diverted in the minimum time, and neglected that side of the problem which required the furnishing of water for the Imperial Valley. (Cory 1914: 1297)

Another proposal came from Captain Mellon: Tow a dirt-loaded barge down from Yuma behind his *Cochan* and scuttle it in the cut. With hindsight, Sykes (1937: 115) thought that "this plan would have succeeded had it been adopted and that the whole course of river and valley history for several years thereafter would thereby have been changed." Rockwood rejected the idea. It seems that his company could not afford it. It was being sued by inundated farmers in the Imperial Valley and by the New Liverpool Salt Company, whose plant on the Salton was in the process of being destroyed. Calexico and Mexicali were also washing away, along with the Southern Pacific tracks into the Imperial Valley.

Through 1905, a number of additional attempts were made to close the crevasse, including by anchoring brush dams to the sandbar built up in the middle of the Colorado's channel, named appropriately "Disaster Island." With its own property at risk, the frustrated Southern Pacific took over the rescue efforts as well as the assets and debts of the California Development Company, and hired engineer Harry Cory to close the breach. It was not until 11 February 1907 that the cut was finally sealed off by dumping tons of rock into it from a temporary railroad trestle across the intake. The Colorado returned to its proper channel and a bona fide concrete headgate was built at the original canal intake above the international line at Pilot Knob (Lingenfelter 1978: 149). By 1916, 300,000 acres of the Imperial Valley were under the plow.

The river, however, had set a dangerous precedent: an urge to overflow with abandon to the north and west. Sykes closes his chapter on the great diversion with a sparse observation that these events "made the following years a period of unceasing vigilance on the part of the irrigation and conservation engineers and converted the investigation of the physiographic developments in the delta during the next decade largely into a study and appraisal of major engineering operations" (Sykes 1937: 63).

Nonetheless, Godfrey Sykes still had a great deal to write about the mostly natural history of the river and the delta into the 1930s, when construction began in Black Canyon, two hundred miles upstream from Yuma. Until the flows began to fill the reservoir behind Hoover Dam in 1935, the river continued more often than not to reach the delta. But it followed a bewildering number of routes, confounded always by its tendency to self-destruct one chosen channel after another with its own deposition, by the alternative processes of vegetative growth and desiccation along channel backs, and by the continued stocasticity of the flow itself. These processes are best illustrated by Sykes' discussion of the low-flow year of 1931, a year that closely mimics the average flow in the lower river in the decades subsequent to the filling of Lake Mead.

In the few years prior to the drought year of 1931, the river had been making one of its major realignments, back toward the historically navigable channel along the eastern side of the delta. Early in 1929, Mexican irrigators cut the Vacanora Canal southward from the river, but when the river rose in the spring, it altered its course and confiscated the canal. Between March and October, "the entire volume of the river [seventeen million acre-feet] was passing through the new channel and entering the canal excavation . . . its further usefulness as an irrigation canal was practically destroyed and it became merely a part of the Colorado River" (Sykes 1937: 84).

Observers anticipated that this event would return the river flow directly to tidewater, ending its tendency in the decades after the great diversion to lose itself in the delta's sloughs and sinks, such the Salton and the great Laguna Salada west of the Cocopa Mountains. This did not happen. As Sykes (1937: 92) recounts, "In spite of its favorable gradient, however, lateral 'whipping,' with the development of abrupt crossings and short radius bends, began to take place almost as soon as the full weight of the river current entered it." Then the low flows of the spring of 1931 fostered deposition in the channel with the net result of "increasing difficulty for the water in finding an exit" (Sykes 1937: 93).

It is worth following Sykes' discussion of the 1931 drought closely, for it was a mostly natural experiment (to be sure, the irrigators and settlers of the Imperial Valley and Yuma intercepted the entire flow that year to ration to their fields) modeling what was to occur with the filling of the lake behind Hoover. Massive vegetational change took place on the delta:

> This prolonged, and perhaps unprecedented, water shortage was observed to have reacted very severely upon plant life in those portions of the delta in which the only source of soil moisture is the periodical overflow of the river. Large tracks of country, untouched by inundation for two successive seasons, were bare and dry. Wild rice (*Uniola palmeri*), quelite (*Amaranthus palmeri*), wild flax (*Sesbania macrocarpa*), and other hygrophilous forms of plant life which normally cover such great areas had either failed to germinate or failed to mature, and the general aspect of the regions normally reached by flood waters, but which had, at that time, failed to receive more than the scantiest supply during the preceding two years, was one of arid desolation. (Sykes 1937: 94)

Sykes makes it clear as well that the paucity of growth compounded the trouble the river was having in reaching the gulf:

> Even the belts of seedling willows which ordinarily cover the upper ends of bars and shoals, and line the banks and swales as the river falls after the spring floods, were noticeably scanty and stunted in growth. These quick-growing thickets are the most effective agency for checking bank erosion and the development of overflow channels when sudden freshets occur, by slackening the velocity of the rising water and allowing it to spread harmlessly

> amongst their roots and stems until the competence of the channel to accommodate the added volume has been increased by bottom scour. (Sykes 1937: 94)

Fish, which Sykes and his companion had greedily caught on the first trek through the delta in 1891 and which the Cucapá had ceased to rely on when ethnologist Kelly visited them in the 1940s, were devastated by this drought:

> [S]ome of the faunal readjustments were even more striking. The various varieties of river fish, which under previous conditions of ample space for development, plentiful food supply, and general optimum environment, had existed in almost incredible quantities in the river channels, had practically disappeared from the entire region between the intake of the Imperial Canal and tidewater. The river had been dry so frequently during 1930 and 1931 and so many changes had taken place in the distributing system during the preceding years, with temporary development and subsequent desiccation of widely separated shallow lagoons and backwaters, that conditions had doubtless become intolerable for their continued existence, although occasional freshets had temporarily filled the channels. . . .
>
> In the brackish waters of the Hardy and the upper portion of the estuary, the gray mullet, carp, and a few other varieties adapted to, or tolerant of, such environment were at times observed to be quite plentiful, although even there the lack of the due proportion of fresh water and the loss of much of the former food supply from the river must have operated adversely both as to their number and distribution. With the increased salinity of the estuarial water, salt-water fish were observed in considerable numbers both there and as far up the Hardy as the limit of free tidal movement. (Sykes 1937: 94–95)

An ample spring flood in 1932 did reach the delta in June, but the major portion of the flow failed, again, to reach tidewater:

> The resulting inundation there was very widespread, water finding its way into dry lagoons and other depressions in the region to the eastward of the Vacanora channel which had not received flood waters for a period of twenty years. To the westward it extended to the Rodriquez Levee, while to the southwestward it

> filled the lower Pescadero basin, flooded the Hardy channel and associated sloughs about the base of the Sierra Mayor, and escaped in considerable volume into the Macuata Basin, filling the Laguna Salada to a length of 8 or 9 miles. (Sykes 1937: 98–99)

Once more the old navigated channel of the Colorado became, in Sykes' precise physiographic terms, incompetent. With the filling of the reservoirs upstream, the issue of competency would become largely moot.

A testy debate followed directly upon the closure of the great diversion just below the international line in 1907. Virtually all the engineers involved in the closure agreed that further riverbank stabilization work needed to be done and done quickly. Opinions differed over the feasibility of controlling the river. The key architect of the closure, engineer Harry T. Cory, wistfully longed for storage dams on the river and its tributaries, but a Reclamation functionary and supervisor of the Yuma Project, Mr. Sellew, broke ranks with his agency and adamantly affirmed that there was only one feasible dam site on the entire system, high up on the Green River in northwestern Colorado. Cory, pointing out the fact that Roosevelt Dam had just been completed on the Salt River, opined in 1913 that "As a matter of fact, many reservoirs will no doubt be constructed on the Colorado river water-shed" (Cory 1914: 1561). He was right.

Mormon Flat, Horse Mesa, and Stewart Mountain Dams, on the Salt River, were erected between 1923 and 1930. Lake Pleasant Dam (now Waddell) regulated the Agua Fria in 1925. Bartlett and Horseshoe, on the Salt's major tributary, the Verde River, went up in the 1930s and 1940s. The Gila River, which Mr. Sellew considered undammable because of its tremendous silt load, was controlled by Coolidge Dam in 1929, then again by Painted Rocks more recently. The mainstem of the Colorado received its own plumbing: Hoover Dam filled to capacity—twenty-five million acre-feet—by the early 1940s. Parker and Davis on the reach below Hoover were completed in 1938 and 1950, respectively. Mexico intervened in this concrete excitement with its own structure in the 1940s, Morelos, to divert its share of the Colorado to the croplands of the Mexicali Valley. Finally, Glen Canyon Dam, begun in 1960 as a substitute for the aborted Echo Park proposal near the site of Mr. Sellew's initial and "only feasible" dam in the entire watershed, filled in 1980.

The purpose of Glen Canyon Dam is to correct a decades-old mistake. When the Colorado River Compact allocated the river's waters between upper and lower basin states and among the lower basin states themselves in 1929, it divvied up an "average flow" into Boulder Canyon of fifteen million acre-feet. Included in the average flow calculations were the years of the great diversion; excluded were the years of drought prior to 1905 (see Jacoby, Weatherford, and Wegner 1976). Ever since, the U.S. Bureau of Reclamation, on behalf of the states and their citizens, has been trying to store surplus water—twenty-seven million acre-feet behind Glen Canyon Dam itself—to make good on this miscalculation. And the United States on behalf of itself has been endeavoring to fulfill treaty obligations it incurred with Mexico in 1944. Through negotiation, Mexico's Mexicali farmers received rights to 1.5 million acre-feet of the river annually, roughly double the quantity they were using in the 1940s but substantially less than is required for the 440,000 acres under cultivation now on the delta. The treaty spoke only to quantity, not quality. It would take another round of negotiations in the 1970s, and a very costly desalinization plant, to address that issue. Nonetheless, the treaty assured that the flow was claimed fully before it got to tidewater.

The Colorado River, which had difficulty reaching the gulf by its own devices as early as the turn of the century, has become, as one writer described it (prematurely, as it turned out), "a river no more" (Fradkin 1981). Winter snows were unusually heavy in the upper basin during the winter of 1982–83, and Glen Canyon Dam, already filled to capacity, could not handle the runoff. To prevent a breaching, engineers raised the level of the dam by installing four-by-eight-foot sheets of plywood atop the spillways, released as much water as they could, and waited for the inflow to subside (Carothers and Brown 1991: 28). The emergency release of water created problems downstream, at Hoover Dam and below. As Joseph Stevens (1988: 264) recounts,

> The flood crested on July 24 when more than fifty thousand cubic feet of water per second was discharged through the diversion tunnels; the spill was continued until September 6, when the drum gates were closed. Millions of dollars' worth of damage occurred in the river corridor downstream from Hoover Dam, but the destruction was only a fraction of what it would have been if Lake Mead had not cut the peak from the flood.

The river ran again in October of the same year—this time from a different origin. A tropical storm, fueled by moisture from the Pacific and the Gulf of California, soaked the Gila and its tributaries—the San Pedro and the Santa Cruz—almost continuously from September 28 to October 3. After wreaking havoc on Clifton, Morenci, Tucson, and other communities, the floodwaters returned toward their point of origin (Saarinen et al. 1984).

A similar flood occurred in February 1993. Coolidge Dam—deemed the most unsafe dam in the county—maintained its integrity, primarily by releasing enough water to inundate Winkelman Flats below. Painted Rock Reservoir expanded to flood acres of adjacent farmland. Much of the Wellton-Mohawk Irrigation and Drainage District on the lower Gila was under water and, finally, the delta itself was partly submerged.

The evidence for floodwater reaching the gulf is contradictory, however. In a dissertation exercise for the University of Arizona, geographer John All measured the expansion and contraction of Laguna Salada from 1989 through 2000. He employed advanced very high resolution radiometer data to replicate what Godfrey Sykes had observed on foot. Peak summer river flows entered the shallow inland depression, then rapidly evaporated. He also mapped the maximum sea level boundaries around the sink and determined that his watered pixels, the Laguna Salada in flood, never crossed those boundaries. His conclusion is a logical one: It is not likely that any freshwater was reaching the gulf (All 2002: 123). M. F. Lavín and Salvador Sánchez (1999) of Ensenada disagree. They took salinity readings in the upper gulf during March and April 1993, following that year's flood. Indeed, they found surface salinity gradients diluted, by as much as five ppt, down the western side of the gulf almost to San Felipe.

The generic life cycle of the genus *Penaeus* would lend support to shrimpers' desires for an augmented river flow into the gulf. Penaeids spawn in open water, with each breeder releasing millions of eggs. Larvae then seek shelter and food in the less-saline waters of bays, estuaries, mangrove swamps, and coastal lagoons. After several months inshore, the surviving sub-adults and adults, known as "recruits" in fisheries terminology, return to nearshore and offshore waters. In the Gulf of California, two technologies are deployed to capture the stock. *Pangas,* small open boats with outboards, work the nearshore waters and the bays with small-mesh gillnets. In the *altamar*, large diesel-powered *barcos* drag trawlnets across the sandy and muddy shelf, harvesting shrimp as well as *basura*, by-catch.

Throughout tropical waters, shrimp harvests show marked interannual variation, and this has led shrimp scientists to a dangerous and dubious proposition. The contention is that there is no connection between the size of the parent stocks surviving the fishery in a given year and the abundance of shrimp the following season: There is no "stock-recruitment relationship" (García 1983). Rather, given the extremely high fecundity of the species, the fishable stock is a function of the survival of post-larvae, juveniles, and sub-adults in the nursery grounds. Hence, commercial success is a function of environmental conditions close to shore (see McGuire 1991b).

Serge García of the FAO, the primary architect of this proposition, offers a caveat: "It is of course obvious that at some high level of effort problems of recruitment can be encountered" (García 1988: 286). Such fishing pressure—the "collapse level of effort"—was reached in the Gulf of California in 1992. But well before that crash, there were troubles in the fishery. Panga and barco fleets expanded rapidly in the 1970s to the point of *economic*, if not *biological*, overfishing. In the early 1980s, there were somewhat perverse efforts to check this expansion. Cooperatives, which since Lázaro Cárdenas' revolutionary time had nominally owned exclusive rights to shrimp, were required to purchase the decaying equipment of the private entrepreneurs who had invested in the expansionary decade of the 1970s. Fleet size stabilized somewhat in the 1980s, but most of the cooperatives never recovered from the debilitating debts incurred in the process.

Stressed to the limits by its own growth and encouraged by the scientific wisdom that there were few such limits to growth, the shrimp fishery faced other assaults in the early 1990s. Under external pressure to "structurally adjust" its economic system, Mexico revoked the privileged position held by the reform sector under the Constitution of 1917. Farming and grazing *ejidos* were no longer protected from outside investment. Similarly, the doors were opened again, officially this time, for private ownership of the shrimp fleets. In the gulf, entrepreneurs quickly acquired offshore trawlers from the banks that had repossessed them from distressed cooperatives. Cooperatives and the regional federations that had given them some political leverage in the past were dissolved. And the new boat owners were selective in manning their vessels, finding politically compliant skippers and crews willing, from desperation, to work for low pay (Vásquez León and McGuire 1993).

Inshore, the small-boat cooperatives weathered the structural adjustment but faced increased competition as the spirit of free enterprise brought new entrants into the fishery, many without prior experience or local roots. The greater threat, however, at least in the upper gulf, came from the regulations proposed for the biosphere reserve. Biologists called for a prohibition on all *chinchorros*—gillnets—used by the inshore fishery, small-mesh shrimp gear, as well as larger nets utilized for finfish, shark, and, illegally, totoaba. Offshore, within the limits of the biosphere reserve, trawlers were to be excluded. That restriction brought the wrath of the private owners and their politically forceful trade organization, the Cámara Nacional de la Industria Pesquera. An unstable and unsatisfactory compromise appears to have been reached now. Trawlers continue to fish the upper gulf and the reserve, in reduced numbers, pulling turtle excluder devices through waters largely bereft of turtle. The inshore sector continues as well, under stricter enforcement of the ban on the totoaba, a prohibition which has been on the books since the 1970s. The sector is adapting, largely through diversification. Species of lesser value are being exploited heavily as compensation for foregone income from shrimp. There is little evidence that the rampant pursuit of the black market has subsided. And there continues to be a resolute suspicion among all commercial fishermen that the presumed benefit of the biosphere reserve—a revitalized ecosystem in the upper Gulf of California—will be of benefit primarily to tourists and ecotourists from outside the region, not locals (see McGuire and Valdez-Gardea 1997).

Scientific controversy persists in the upper Gulf of California. The prominent Mexican biologist Bernardo Villa rejects the contention that drastic change has occurred in the ecosystem as a result of lack of freshwater flows:

> [T]here is no information to substantiate this hypothesis. In fact, evidence suggests that the Río Colorado delta behaves as a very fertile coastal lagoon, supporting abundant populations of crustaceans and mollusks . . . and that substantial numbers of bottlenose dolphins utilize the delta. . . . There is no evidence to suggest

> that this apparent richness is different from naturally occurring conditions of the past. (Villa-R. 1993: 9)

Villa gets some support from Saúl Alvarez-Borrego and his colleagues at two prestigious institutions in Ensenada, the *Instituto de Investigaciones Oceanológicas* of the *Universidad Autónoma de Baja California* and the *División de Oceanología* of the *Centro de Investigación Científica y de Educación Superior de Ensenada*. Recently, though, one of these researchers has begun to dissent, returning to the received wisdom of most ecologists and virtually every fishermen in the upper gulf: The decline in freshwater inputs has had a significant and deleterious effect on the health of the sea. Salvador Galindo-Bect discovered a possible correlation between improved shrimp landings at San Felipe and high river flows (themselves in turn correlated with the high precipitation resulting from El Niño–Southern Oscillation events). He acknowledges that the catch data are crude—annual, legally reported landings and number of operating trawlers, not actual fishing effort. But he posits a cause. In the absence of the resisting force of river flow, the saline water mass of the gulf moves up the estuary, carrying a full complement of predators to harvest the fauna that has sought refuge and food in the nursery grounds (Galindo-Bect, personal communication, June 1996; cf. Galindo-Bect et al. 2000).

Studies elsewhere suggest that this hypothesis—the loss of a water-mass barrier between ocean predators and the dwellers of the estuary—may be plausible. Philip Williams has examined the San Francisco Bay estuary, whose sources of freshwater, the Sacramento and San Joaquin Rivers, have been diverted for irrigation in California's Central Valley. As he summarizes,

> Phytoplankton abundance in the main channels of the estuary can be greatly reduced during extended periods of low flow due to the intrusion of marine benthos into what was formerly the brackish zone. The intruding species (such as the soft-shelled clam *Mya areniia*) tend to be voracious filter feeders . . . and their grazing of phytoplankton limits the food supply available to other zooplankton . . . [which] in turn, serves as a food supply for valuable fish. (Williams 1989: 292)

Few direct efforts to correlate river discharge and productivity in the upper reaches of the Sea of Cortez have been made. The most notable, Flanagan and Hendrickson's 1976 study of the totoaba fishery, could not unambiguously attribute the decline in totoaba stocks to decreased river flow (Flanagan and Hendrickson 1976).

The story is complex. Totoaba migrate to the mouth of the Colorado annually to breed in its brackish waters, so changes in flow appear to have degraded its spawning and nursery grounds. Between 1942 and 1958 the decline in totoaba catches is correlated with declining, erratic flow of the Colorado River. The relationship between flow and catch for this period suggests some flow-related quality was important to the nursery ground. Following 1958, though, flow varied little, the catch increased to a secondary peak, but then crashed. The initial increase was probably due to the declaration in 1955 of a breeding reserve at the mouth of the Colorado River. While the reserve offered some temporary relief from exploitation, totoaba continued to be caught legally outside the reserve until 1975. Although there is now a ban on totoaba fishing, poaching continues. The schooling of totoaba in the shallow, muddy waters at the mouth of the Colorado makes them easy prey for fishermen, and overfishing is likely to have played a significant role in their decline.

Studies elsewhere find some strong relations of rainfall and shrimp stock sizes. Over a period of thirty-eight years, Gunter and Edwards (1969) found a significant correlation (at the 0.1percent level) between stocks of white shrimp (*Penaeus fluviatilis,* now *P. setiferus*) and rainfall in Texas for the two preceding years. . But the correlations did not hold for brown shrimp (*P. aztecus*), nor were they found in the adjacent Louisiana shrimp fishery.

Zein-Eldin and Renaud, in a subsequent review of the literature on inshore environmental effects on shrimp along the Gulf of Mexico coast, observe that the *interaction* of water temperature and salinity may have more profound effects than either factor alone. Their outline of a water management regime to enhance shrimp stocks suggests indirectly some of the complexities shrimp face in their growth:

> [I]t would appear that water flow could be restricted during the early spring months, when cold fronts are still likely, to minimize the negative effects of the combination of cold and low salinity on young brown shrimp. Conversely, water inflow would be most necessary during the late spring and summer in the presence of young white shrimp needing salinities below 25 0/00 and perhaps less, during the warmer months (August–September) of the year.

> As temperatures decrease in the fall, control of water flow might again be important, since it appears that in postlarvae of both species, survival is better at higher salinities than at $5^{0/00}$ or less as temperatures decrease to 180 C or less. Penaeids may require variable water flow into nursery areas depending on season, and perhaps on particular year, e.g., early or late entrances of postlarvae into a given system (Zein-Eldin and Renaud 1986: 11).

Thus, in theory, river management for the enhancement of species and habitats is possible. But this calls for fine-tuning of seasonality, salinity, and temperature. Even if the pulse flows eyed by the Pacific Institute and its collaborators were to reach the sea, they may not be sufficiently finely tuned and timed. And they may help, on average, one year in four.

With the river no more, the aquatic ecosystem of the northern Gulf of California nonetheless continues to show very high levels of primary productivity. B. Zeitzschel of the Scripps Institution of Oceanography was one of the first to systematically assemble the accumulating data on the productivity of the gulf. His conclusions have since been replicated a number of times: "[T]he primary productivity in the Gulf of California is comparable to the productivity in areas such as the Bay of Bengal, the upwelling areas of the west coasts of Baja California or North Africa. It is about 2 to 3 times greater than that in the open Atlantic or the open Pacific at similar latitudes" (Zeitzschel 1969: 206).

Within this rich sea, Zeitzschel's most northerly research stations—in the upper gulf around latitude 30° N—showed the highest primary productivity measures for the entire gulf. Subsequent work has restored some of that honor to the Guaymas Basin and to upwelling areas along the Sonoran coast near the Midriff Islands (see Alvarez-Borrego and Lara-Lara 1991), but the upper reaches continue to impress observers (Alvarez Borrego et al. 1978; García de Ballesteros and Larroque 1974; Gendrop Funes, Acosta Ruiz, and Schwartzlose 1978; Valdéz-Holguín, Eduardo, and Lara-Lara 1987). And the estuary of the Colorado—now a negative estuary with salinities increasing from the mouth to the interior—showed very high concentrations of nutrients (nitrite, nitrate, phosphate, and silicate) when sampled in 1989 and 1990 (Hernández-Ayón et al. 1993).

What accounts for the remarkable and continued fertility of the northern gulf? Most observers credit the scouring action of tides and currents on the millennia of accumulated sediments from the river—

deposited at a rate of perhaps 180 million tons a year (Thompson 1968: 77). The most significant oceanographic pattern in the area is the extreme tidal fluctuation operating on the local bathymetry of the region. The relatively shallow and extensive continental margin amplifies the effect of the tides, exposing extensive areas of the shallow continental shelf. High tidal fluctuations promote the movement and cleansing of the sediments, resuspending fine particulate organic and inorganic matter and other nutrients that reside in the mud. These processes supply oxygen to the continental shelf and increase the availability of nutrients (see Zedeño and Aubert 1993: 76).

Much discussion has centered recently on another mechanism for enriching the waters of the upper gulf that was hypothesized by J. Y. Gilbert and W. E. Allen (1943) in the 1940s: a north-south exchange of water driven by heat flux. M. F. Lavín and S. Organista have summarized the current wisdom:

> [T]he high-salinity water created by evaporation cannot sink because of the dominating effect of heating. Therefore the basic circulation pattern would have to consist of an output of warm, salty water at the surface and compensating input of cold fresher water at depth, i.e., the reverse of the Mediterranean . . . Bray . . . proposes a three-layer circulation, with the 0–50 m surface layer responding seasonally to the winds, a 50–250 m layer of outflowing gulf water, and an inflowing layer between 250 and 500 m. This inflow of deep, less salty, cold, and nutrient-rich water may be responsible, together with tidal mixing, for the high biological productivity of the central and northern gulf. (Lavín and Organista 1988: 14,035; see also Bray and Robles 1991).

The combined actions of the tides, the winds, and the circulation of water have shaped and sorted the floor of the northern gulf. Along the western edge, from San Felipe to the head of the gulf, there is a gently sloping and smooth plain, characterized by fine silty-clay deposits. To the northeast, the bathymetry is irregular, consisting of a series of parallel low ridges (bajos) and troughs of about eight to ten meters in relief, running intact for twenty to thirty kilometers. There is evidence of the former river as well—a prominent, V-shaped channel running from Isla Pelicano at the mouth of the estuary southward toward Wagner and Delfin Basins (Thompson 1968). The bottom composition on the Sonoran side is predominantly coarser sand which, compared to the silt-clay plain on the other side of the gulf, supports a relatively depauperate marine fauna. Shrimp fishermen are cognizant of the difference. Trawling along the shallow bottoms of the western side of the upper gulf yields too much by-catch. Along the sandy, steeper, and deeper Sonoran littoral, trawling is relatively more efficient—a larger yield of shrimp relative to by-catch. But this area is less popular, because the deeper waters yield primarily brown shrimp of less market value than the shallow-water blues (Zedeño and Aubert 1993).

The ultimate destination of the Colorado River's nutrient-rich load appears to be—still—the deep basins of the northern gulf, Delfín and Wagner. One of these basins, Delfín, was cored to "evaluate the response of the Gulf of California to historic effects of reduced river discharge" (Baba, Peterson, and Schrader 1991: 590). The "mass accumulation rate of terrigenous sediments" remained constant, before and after the damming of the river. These researchers come to a tentative conclusion that does not bode especially well for the far northern gulf in future centuries: The deposits now entering the Delfín most likely are the very same ones that were deposited in the upper gulf in geologic time and have long underwritten the productivity of the region (Baba, Peterson, and Schrader 1991: 602).

One of the green lagoons of the delta has come back to life after decades of the desert diaspora that Sykes began to witness early in the century. The Ciénega de Santa Clara, like so many other features of the deltaic landscape, is both a human and a natural creation. It is a 20,000-hectare wetland straddling the old pre-1905 river channel on the eastern wing of the delta, revived to a landscape that mimics those Aldo Leopold and his brother trekked and hunted. Vegetation native to the delta's wetlands flourishes, attracting an abundance of wildlife that includes some eighty species of birds and providing refuge for the endangered desert pupfish (*Cyprinodon macularius;* see Minckley and Deacon 1991) and the Yuma clapper rail (*Rallus longivorstris yumanensis*).

In 1974, the Ciénega consisted of only two disjoined sections, 30 hectares and 180 hectares in size (Glenn et al. 1992: 820). The area was then chosen by the Bureau of Reclamation as the eventual depository of the briny waste from the massive Yuma Desalinization Plant. In its design, the plant would take some 160,000 acre-feet of wastewater from the Wellton-Mohawk Irrigation and Drainage District, with a salt content of 3,000 ppm, force it through membranes, and produce annually some 80,000 acre-feet of desalted (300 ppm) water. This would then be blended with raw water from the Colorado River to deliver the 1.5 maf of irrigation water to Mexicali called for under the Mexican–United States Water Treaty of 1944 and a salinity agreement in 1973 (Furnish and Ladman 1975; Holburt 1982). The "reject water" from the Yuma plant—at 10,000 ppm—would then be drained into the delta.

Over the reasoned objections of most economists that there were much more efficient ways to meet the water-quality provisions Mexico extracted, primarily by better water management in the citrus groves of Wellton-Mohawk (see Martin 1975; Van Schilfgaarde 1982), the desalinization plant was built. It cost around $300 million, with an additional $30 million a year to power it. Originally, the Bureau of Reclamation contemplated a nuclear reactor down near El Golfo de Santa Clara, along the San Andreas Fault (cf. Thomson et al. 1968). The desalinization plant has never been used much. As an interim measure during the plant's prolonged period of construction, the Wellton-Mohawk Main Outlet Drain Extension—MODE—passed agricultural runoff directly into the Ciénega at Santa Clara, not to the irrigated fields around Mexicali. And U.S. officials discovered that there was enough water in the river and in storage to meet its treaty obligations to Mexico. Website technicians for the Bureau of Reclamation give this spin to the $300 million desalting project:

> In recent years nature helped Reclamation maintain the quality of water delivered to Mexico—several periods of high Colorado River flows occurred during YDP's construction and freshened the water being delivered to Mexico. Reclamation completed construction of the YDP in 1992 and began operating the plant at one-third capacity, but in 1993 a 500-year flood event occurred on the Gila River, dumping almost 5 million acre-feet of water into the Colorado River. This allowed Reclamation to take the plant offline until salinity again rises in the Colorado River, thus saving taxpayer dollars. (U.S. Bureau of Reclamation 1997)

The YDP, unused except for its research and development–oriented Water Quality Improvement Center, is now technologically obsolete. However, Ed Glenn of the University of Arizona's Environmental Research Lab, a student of the ciénega, counsels vigilance. Should pressure mount to turn the plant back on, the lagoon would receive unacceptable brine instead of its current supply of agricultural wastewater (see Pitt et al. 2000).

Frank Wilson's 1994 proposal for "international instream flow rights in the lower Colorado River" is substantially more ambitious than the desire of Glenn and his colleagues to maintain the re-created green lagoon at the tail end of the MODE. Wilson's scenario unfolds roughly as follows: Mexico would negotiate an agreement with the United States for an instream flow right to protect the endangered totoaba and vaquita, in accordance with the goals of the biosphere reserve. The United States would invoke its federal powers over state water rights, based on the Commerce Clause of the Constitution, which gives Congress regulatory control over once-navigable waters (on the Colorado, a legal fiction for almost a century), to enter into such an agreement with Mexico and acquire the necessary water. As many others have before and since, Wilson sees one potential source, some 370,000 acre-feet from the Wellton-Mohawk Irrigation and Drainage District outside Yuma. At one time, Senator Edward Kennedy had proposed a buyout of that entire district to resolve the water claims of the Indians of central Arizona.

With an international treaty for instream flow in place, Section 7 of the Endangered Species Act—its muscle—might then be flexed. As it now stands, the extraterritorial extension of the ESA is ambiguous and water agencies in the United States are not yet accountable for habitat destruction in Mexico. The proposed treaty for instream flow would obviate that. Wilson concludes,

> Agencies will no longer be "saved" if there is an instream flow program. If there is the legal means for allowing water to reach the gulf, and if a lack of that water would threaten the continued existence of the totoaba, then an agency must, under Section 7, do what it can to move water to the delta. An agreement with Mexico allowing water released by the United States to reach the gulf would shift the formula for agencies operating along the Colorado. As permits for water use from the dams were renewed, as operation plans for the dams were reviewed, as hydroelectric projects were reviewed by the Federal Energy Regulatory Commission, the plight of the totoaba would demand attention. (Wilson 1994: 261–62)

Were such a scenario to come to fruition, Wilson (1994: 271) believes, the major beneficiary would be Mexico, through enhanced potential for ecotourism in the delta; a revitalized totoaba fishery which, if done with hook and line rather than gillnets, would protect the vaquita; and the reestablishment of a salinity barrier at the mouth of the estuary to protect juveniles of several species from predation. He suggests an aesthetic benefit accruing to the United States as well: "Mexico has become attractive to US tourists. Reestablishing the delta described in the *Sand County Almanac* would provide a real 'place'" to go and visit with the spirit of Aldo Leopold, father of the 'ethic of place'" (270).

At least some of these new visitors would be unhappy campers under Wilson's proposal. There are only sticks, no carrots, here. Users and overusers of a river held hostage to the Endangered Species Act are unlikely to search for creative ways to release water. And, should such water be extracted from them by the courts of law, they are unlikely to countenance any commercial use of the upper gulf by the people who reside there.

Robert Glennon and Peter Culp reach a similar conclusion for a similar attempt to invoke the ESA, the lawsuit by the Defenders of Wildlife against Gale Norton, Secretary of the Interior. Assessing the political climate that is becoming increasingly hostile to environmental protection, these legal scholars suggest that the

> continued and growing reliance on the ESA by certain environmental groups as a "workhorse" for litigating controversial issues is a potentially dangerous strategy, both politically and legally. In our view, not every case is appropriate for the application of the ESA, which is undoubtedly the "biggest gun" in the environmental arsenal. At present, the ESA is frequently used not to protect listed species, but instead to block popular developments by "species shopping" in a particular area to find a listed species. (Glennon and Culp 2002: 962)

Glennon and Culp warn that if the Defenders prevail, Congress might simply exempt the entire lower Colorado from the Endangered Species Act, as it did for Tellico Dam and its beleaguered snail darter. To date, though, the Defenders of Wildlife have not prevailed. In March 2003, a federal district court in Washington, D.C., dismissed the suit, concluding that the Bureau of Reclamation has no excess water under its discretionary control to release through the delta. It is bound by the Law of the River: "a Supreme Court injunction, an international treaty, federal statutes, and contracts between the government and water users that account for every acre foot of lower Colorado River water" (*Defenders of Wildlife v. Norton* 2003: 40).

Aldo Leopold wing shot quail and geese in the wetlands of a delta whose river was already incompetent. Some freshwater may have reached tidewater during the events of 1983, one on the Colorado system that nearly breached Glen Canyon Dam, the second on the Santa Cruz–Gila watershed that ripped out bridges in Tucson and inundated croplands from Marana to Yuma. These may have rivaled the floods witnessed by Sykes and the engineers early in the century, but except for the testimony of fishermen in the upper gulf, there is little direct evidence of the ultimate destination of the flows. Again in 1993, the main system experienced what Yuma's Reclamation office, with hyperbole, tagged a five hundred–year event. Fishermen who had stopped work during the economic and biologic crisis of the early 1990s returned to El Golfo de Santa Clara with high expectations.

Such episodic events in the future will keep those expectations alive. There is enough concrete in the river to allow that river to be manipulated for ecological benefit. And there is sufficient acceptance of an ideology of habitat restoration through scientific management. But science, as yet, seems inadequate to the task. Not enough is known about the species-specific requirements of organisms in the upper gulf, nor of the dynamics of that complex ecosystem. The presumption that this ecosystem now, as in the past, is ultimately dependent on the river, has some skeptics. But certainly, Sykes, Leopold, and the present inhabitants of the upper gulf would not, each for quite different reasons, be averse to seeing freshwater flowing to tidewater. This is not a panacea, however.

Propositions calling for the restoration of the delta and the sea deflect attention from the problems of that fishery. A surer way to promote the recovery of totoaba stocks is to prevent them from being fished, for commerce or sport. A better way to restore the economic and biologic viability of the region is to prevent overcapacity in the fishery, not to promote the ever-increasing influx of outsiders. The ecosystem of the Gulf of California has been productive and resilient. With the careful stewardship of human users, it can continue to be so.

The delta's habitat can be enhanced, but it is unlikely that the water to do so will come from the courts, nor be freed up by the agencies responsible for managing an overappropriated stream. Sixty million acre-feet are stored behind the system's dams. The Pacific Institute and its allies sought a small share of this—32,000 acre-feet a year and a 260,000 acre-foot pulse flow every four years. With effort, persuasion—and money—these quantities could be found in the system. It is somewhat disingenuous, though, to pretend that the aquatic needs of the gulf will be satisfied by habitat restoration on the delta. ❖

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