SAN FRANCISCO

ESTUARY

Almanac of Restoration

New lessons from old projects.
Experiments with scope and scale.
Beyond the low-hanging fruit.
If it's not hard, it's not worth doing.

Bouldin Island, Sacramento River,
Clear Lake, Lookout Slough, Putah Creek,
Suisun Marsh, South Bay Salt Ponds,
Novato Baylands, Heron's Head, Bay Trail,
San Mateo Creek, and more

WATER
ENVIRONMENT
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Table of Contents

A special almanac issue celebrating restoration and 30 years of Estuary reporting.

EDITOR'S NOTE

A Hundred Ways to Cherish the Estuary

Restoration is a powerful concept. Physically it entails putting something back, making it right again; emotionally it requires hope for the future, a sense of something worth doing.

In the Estuary, restoration is no longer about recreating some pristine ecosystem that once was. The vast marshes that carpeted the Delta and circled the Bay before Europeans arrived out West are long gone; the great rivers spilling fresh water and salmon downstream are a shadow of their former selves; the myriad creeks and sloughs offering migratory paths and habitats for so many estuarine creatures are now laced with obstacles and lined with concrete.

But for some time now, the call to restoration work has been growing. People in all walks of life have answered the call — scientists, engineers, farmers, activists, politicians. Young people and families have gone out to pick up trash and plant natives. Bird buffs have gathered every year to count avian migrants overhead. Creek adopters have rebuilt eroding banks and carried steelhead around dams so they can reach spawning grounds. A succession of government programs have committed and recommitted to saving the Delta, the endangered, the baylands, water quality, and more — urged on by the champions of the environment. Politics often intervene in reaching ambitious goals but somehow most people still support ecosystem restoration in some form. It feels good.

In this special issue of *Estuary News,* we celebrate restoration in all its forms and sample projects of every kind. We review a few ways in which we are measuring our progress: did the birds and fish come back? And we delve deeper into some of the latest iterations of restoration: centering equity in access to open space; combining flood control with habitat creation in multi-benefit projects; responding to sea level rise with nature-based solutions. The field of restoration, here in our Estuary, reflects myriad fascinating nuances.

In this special issue we also include stories representative of the different landscapes and waterways that make up our Estuary, starting high up in the watersheds with rivers, lakes and creeks, moving into the Delta and upper Estuary, and then exploring efforts all around San Francisco Bay (every project discussed appears on our centerfold map).

Sprinkled throughout we also offer some retrospective perspectives and reviews of the changes in our thinking over the decades since we decided, sometime way back when, to try to fix an ecosystem so altered, so remade, it is hard to imagine it healthy ever again. And yet we continue to imagine just that.

In our online version of this story, we also celebrate some of the voices of restoration, asking practitioners of several generations how they got into the field, why we should restore this ecosystem, and what were *aha* moments in their experience and times when they changed their mind.

None of this effort — in storytelling and recording — touches the tip of the restoration iceberg. While we couldn't cover every story now, we have likely covered most in the past.

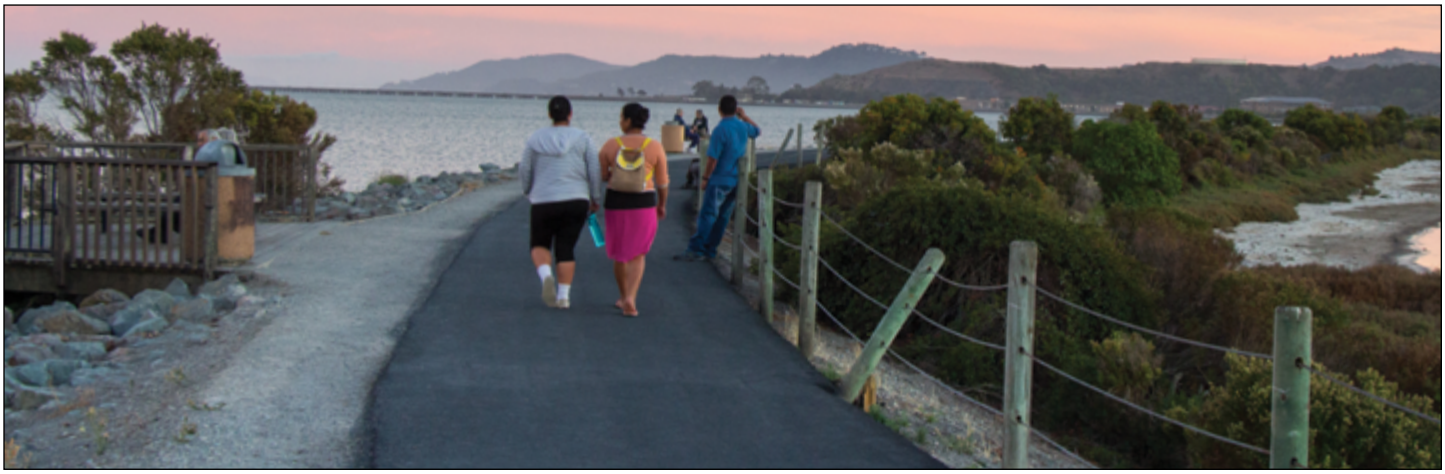
Which all seems like a good way to both honor the work all of you are doing and we have done to cover it as we announce that this will be our final issue of *Estuary News*. After 30 years of building a community around Estuary stories and storytelling, it is time for us to leave the scene and make way for something new. We had a good run, and we thank you for your loyal readership. We've built an amazing storytelling tradition around the one thing so important to us all: the water that runs through our home. Keep telling those stories! Keep making it right! We'll be listening.

ESTUARY NEWS TEAM

BAY TRAIL

Boots on the Bayshore? Evolving Perspectives

NATE SELTENRICH, REPORTER



Bay Trail in Richmond. Photo: Karl Nielsen

It's largely taken for granted within the San Francisco Bay environmental community today that public trails through parks and preserves are both right and good: right, in the sense that they can offer equitable access to our region's most treasured natural assets; and good, because they engender support for protection and restoration. But along the waterfront, trails weren't always so welcome.

"The local chapters of the Audubon Society and the Sierra Club were adamantly opposed," recalls Tom Mikkelsen, who led implementation of the Bay Trail, an ambitious multi-use trail ringing the Bay, from its inception in 1988 until 2001. "Every time we came up with a project that was close to the edge of the Bay, they opposed it. The issue was that the shoreline "had to be preserved, and preservation was the first order of business.'"

Their concern that more access to the shoreline would imperil its remaining habitat was not entirely unfounded. It likely came as an overcorrection for abuses the Bay had suffered in previous years through dumping and infill, damages that gave rise to the Bay Area environmental movement in the first place. Yet slowly, over the course of decades, the once-paradoxical concept that access might translate to protection became common sense within the restoration community. "They eventually saw these things as mutually supporting," Mikkelsen says.

During his 13-year tenure, the San Francisco Bay Trail grew by almost 100 miles. The system's total mileage today is just north of 350, with 150 more needed to complete the trail. But the annual growth rate has slowed to a crawl as only the most difficult segments remain.

One recent addition exemplifies how current roadblocks to Bay Trail expansion aren't political in nature, but logistical. More importantly, it illustrates the progression of public-access goals since the late 1980s, from simply building trails to prioritizing equity and community engagement.

India Basin site plan. Map: SFRP

When complete in the summer of 2026, the India Basin Waterfront Park Project will transform a section of San Francisco's shoreline in the Bayview-Hunters Point neighborhood from a polluted former industrial site to a thriving natural area and gathering spot with a restored shoreline. It will also close a small yet critical gap in the San Francisco Bay Trail and serve as the midpoint of the 1.5-mile India Basin shoreline trail, which spans a total of seven properties including restored Heron's Head Park to the north.

Part of the project area was so degraded by previous uses (with no existing marsh to preserve) that multiple trails, docks, buildings, and recreational facilities could be considered from the start — with community input — right alongside plans for upland plantings and new shoreline and wetland habitat. Public access and environmental restoration goals were considered together throughout the design and permitting process, says San Francisco Recreation and Parks Department project manager David Froehlich.

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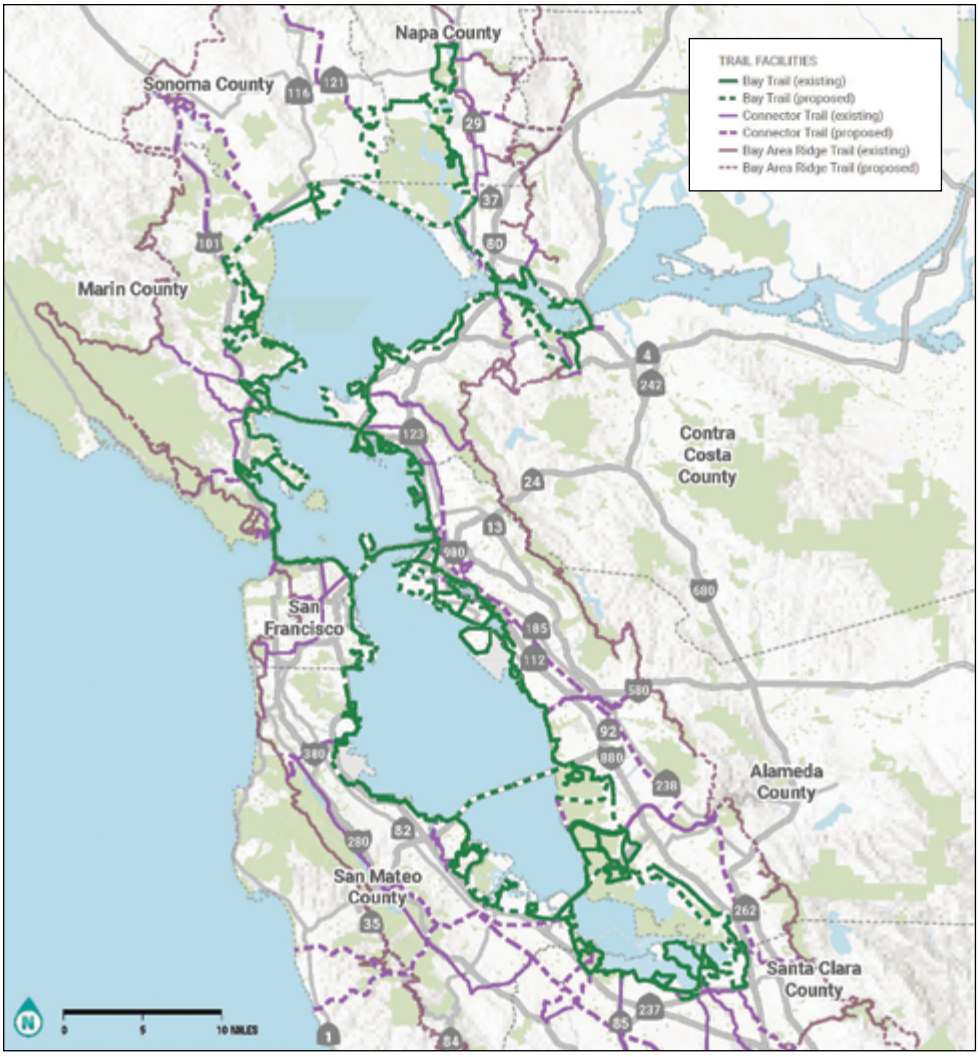

San Francisco Bay Trail: Map: ABAG

SF Rec and Parks, which owns the land, collaborated particularly closely with the Bay Conservation and Development Commission (BCDC), Froehlich notes — an organization whose mission, alongside protecting and enhancing the Bay, involves providing public access.

Similarly, the voter-approved San Francisco Bay Restoration Authority, which contributed nearly $5 million to the project's $200 million budget, considers public access an essential element of its mandate. So does the State Coastal Conservancy, which helps run the Restoration Authority; in recent years, its concept of access has broadened well beyond the Bay Trail itself to include other design elements that are responsive to community needs, as well as transportation to and from shoreline parks and trailheads.

The pandemic has accelerated this ongoing evolution in thinking at agencies around the Bay, says San Francisco Estuary Partnership director Caitlin Sweeney. "It really drove home the point that access to open space is so critical for our health and well-being, but is not provided equitably throughout our region," she says. "I think that's where we're going to see the push. We're also going to see an acknowledging of the different ways we use open space."

Still, public access must remain compatible with other goals. Different agencies with which the Coastal Conservancy partners manage different properties for different purposes, says deputy program manager Jessica Davenport. For example, "there are California State Parks that are more oriented toward public access and recreation. But California Wildlife Areas are primarily for wildlife." There, public access is, by law, "focused on wildlife-oriented recreation, like fishing, hunting, bird watching, and nature study, [and] they have a very limited budget to maintain public facilities," Davenport says.

Case in point: the California Department of Fish and Game's Napa-Sonoma Marshes Wildlife Area. If India Basin is on one end of the public-access spectrum among San Francisco Bay wetlands, this vast tidal complex surrounding Highway 37 is on the other: difficult to access (mostly by boat) and ultimately managed for wildlife.

The area also includes the largest remaining gap in the San Francisco Bay Trail, planned to one day follow the highway's path across the marsh. Mikkelsen says he remains optimistic, just as he was in the late 1980s, that the trail will eventually be completed. "I'd hoped to see this thing done by the time I retired," he says. "That didn't happen. So now I'm hoping that I'll see it by the time I kick the bucket. And that may may not happen. But maybe my kids or their children will be able to [see] it, and I think that's terrific."

After all, few experiences are more inspirational, and more motivating to continue to protect this regional centerpiece, than reaching the Bay's edge, peering over sinewy channels of healthy tidal marsh toward miles of open water, and contemplating how far we've come.

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From Sticks to Satellites: Restoration 1960-2023

ISAAC PEARLMAN, REPORTER

The 1960s and '70s were a time of rapid change for the San Francisco Bay shoreline. It had long been treated as a waste disposal site or area to fill for development, but public outcry for protection reached a crescendo in 1969 with the birth of the San Francisco Bay Conservation and Development Commission (BCDC). The passage of the federal Clean Water Act in 1972 meant that destruction of wetland habitat — already 90% vanished from the Bay — had to be mitigated, or re-created elsewhere. For the first time there was public support and a legal obligation to restore wetlands, but scientists had to figure out how.

Measuring sediment accretion at Hamilton wetlands restoration site in Marin County. Photo: ESA

On June 3, 1976, an intrepid group of restorationists in the small Marin County town of Corte Madera kicked off one of the biggest and boldest restoration experiments undertaken in the Bay Area to date: returning 128 acres of sunken land to the tidal embrace of the San Francisco Bay. Their working materials included a large pile of thick mud leftover from the creation of the nearby Larkspur Ferry Terminal, a field that had been diked off for agriculture and development decades ago by Domenic Muzzi, and the unproven hope that the Bay's nutrient-rich waters would do most of the heavy lifting by allowing marsh vegetation to naturally establish.

"Restoration projects had very targeted and simplistic objectives back then," says Stuart Siegel, who cut his teeth on the restoration of Hoffman Marsh in Richmond during the mid-1980s. Siegel, who today is a San Francisco State University research professor and interim director of the San Francisco Bay National Estuarine Research Reserve, says the early days were simply about trying things to see what happened. "The restoration goals really were: are tides reaching the restored area, are you seeing the right vegetation, and are birds coming back?"

Just a few years prior to the attempt to bring back Muzzi Marsh, it was widely believed that a tidal salt marsh could never be restored. Now, restorationists led by the legendary wetland biologist Phyllis Faber were in the midst of "uncharted territory" as she called the fledgling Muzzi Marsh experiment in a 2015 interview.

In those early days there were no wetland design criteria, restoration science, or success metrics to draw from. Nor even the most basic data: in the book *Natural History of the San Francisco Bay*, early restoration pioneer Phil Williams recalls organizing shifts of volunteers to note the tidal height on measuring sticks stuck in the mud every 15 minutes — for 30 hours straight. No simple equipment existed to measure water velocity, so field researchers often deployed the "Luna Leopold" method of planting two stakes a known distance along the water and then tossing in orange peels to measure the current speed.

Muzzi Marsh site map. Image: ESA

This trial-and-error beginning to tidal restoration meant that early projects were educational laboratories. The expectation at the time was the Muzzi project would quickly develop into a mature, vegetated marsh. But restorationists learned from their first attempt that simply leveling the site to the high tide height didn't produce enough tidal flow over restored areas, which in turn created low plant survival. As a consequence, Muzzi's inner site failed to develop the same channel and topographic complexity that the outer marsh formed on its own from the tides, and later restoration work excavated more channels in order to extend the Bay's reach inland.

Some lessons were as simple as learning how to work in viscous mud. "You're not a salt marsh ecologist unless you've left behind a boot or three," laughs Donna Ball, senior scientist with the San Francisco Estuary Institute and 20-year wetland restoration veteran.

Siegel admits to having "donated" many boots to the marsh during his early years. Nowadays hip and chest waders are standard gear, with Siegel's SFSU colleague Katharyn Boyer improvising use of wetsuits and boogie boards to stay above the muck — though getting stuck is still a timeless initiation to wetland work.

Some of the early restoration sites never panned out: Warm Springs Marsh in the South Bay was restored

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Sonoma Baylands over time. Image: ESA

in 1986, but according to Siegel is still unvegetated mudflat today. Similarly, a site in Richmond called the Nevada Parcel due to its shape, never evolved into tidal wetland.

Muzzi Marsh, however, is now part of the Corte Madera Marsh Ecological Reserve, where raptors soar overhead, shorebirds bob beaks into soft Bay mud, and salt marsh harvest mice hide out under extensive pickleweed. The wetland is home to the one of the Bay's largest populations of endangered Ridgway's rail. The marsh is now among the most studied restoration sites in the Bay that — to the delight of the countless folks who have contributed to, and learned from, one of the longest restoration monitoring datasets in the San Francisco Bay — is still evolving today.

A Regional View of Restoration

In 1987, a new amendment to the Clean Water Act forced municipalities to regulate polluted storm runoff, greatly reducing Bay contamination, though several large oil spills still muddied the waters ... and marshes. In this era, tidal restoration mostly driven by required mitigation was picking up steam: by 1998 about 4,000 acres of tidal wetland had been restored to the San Francisco Bay. New projects now had restoration data and science to guide them — but there were still plenty of lessons to learn.

In July 1994, the Sonoma Baylands wetland restoration officially kicked off with a ceremony attended by then-Vice President Al Gore. The 300-acre project, subject to a White House task force and endorsement from Bill Clinton, was opened to the tides in October 1996 when Bay water rushed on to land it hadn't touched for nearly 100 years.

Unlike the restoration of Muzzi Marsh 20 years prior, restorationists opted to deliberately underfill the Sonoma Baylands site with dredged sediment, leaving it 18 inches below the high-tide mark. This would allow the Bay's nourishing water to wash over the area like a balming salve, dropping fine sediment and naturally grooving sinuous channels on the tide's way out. As one of the first restoration projects to formally incorporate available monitoring data into its design, the Sonoma Baylands effort marked a shift to "second-generation" projects built on 20 years of hard-earned marsh restoration knowledge. It also represented a regulations breakthrough in providing a home for sediment from the Oakland Harbor, as dredging had been stymied for years by a lack of soil disposal options.

Both the Sonoma Baylands and the 1999 restoration of San Francisco's Crissy Field also featured a new design element: deliberately piled "islands" of sediment in the middle of future marshland, which created nesting habitat for birds but came with the additional benefit of buffering the area against wind and waves. In addition, the Crissy Field project pioneered a different type of innovation: human resources. Thousands of community volunteers contributed labor to help restore the dunes and marsh, and enthusiastically participated in more than 100 public meetings. As a result, with its elevated boardwalk and perimeter paths, the project was one of the first to integrate public access with sensitive habitat restoration. (See p. 3 Bay Trail.)

"I came to the Bay Area restoration community from a small town in Washington State," says Ball. "It surprised me when I arrived how much support there was for restoration in an urban area like the San Francisco Bay."

As these second-generation restoration projects matured, they uncovered more lessons for scientists. Sonoma Baylands was limited by its existing small Bay channel, which restricted the amount of alimentary tidal flow to the inland restoration area and created more mudflat than marsh vegetation. As a consequence it took more than a decade longer than expected to develop marsh habitat, though eventually a beautiful dendritic marsh plain did form. Crissy Field, with its complicated and shifting beach shoal, became more of a lagoon than wetland requiring periodic dredging and maintenance rather than the tidal flushing initially imagined.

In the 1990s maps of the San Francisco Bay, which had mostly ignored marshes and Baylands except for navigation purposes, began to reflect satellite radar, infrared, and other spectral imaging that for the first time revealed in richly intricate detail the complex and dynamic boundary between the land and Bay. As environmental science and monitoring data proliferated like an algal bloom, restoration projects began to attract biologists, geomorphologists, coastal engineers, hydrologists, and other specialized experts.

"We now work together a lot more now than we did in the past," says Ball, remarking how satellite imagery and data on parameters from marsh elevation to sediment supply are just a collaborative phone call away. "Early salt marsh work involved people out there with measuring sticks. Technology now helps us a lot — for example, we can now learn a lot more detail about [marsh] systems through remote sensing."

In spite of all the progress, a 1999 comprehensive review of San Francisco Bayland ecosystems concluded that "the science of wetland restoration is still in its infancy." Critical questions like "what does wetland restoration success actually look like?" were still open for debate. Although restorationists ushered in rapid advances in wetland research and data, the community wasn't always able to benefit. In this era before widespread internet use, a significant amount of monitoring reports, data, and key studies remained tucked away from public view in the dusty record-room cabinets and bookshelves of agencies.

As data expanded our view of wetlands, it also began to offer a tantalizing glimpse of the Bay as a whole. In the late '90s, the Bay Area's top 100 scientists and regulators convened to identify 120 species to serve as proxies for Bayland ecosystem health, and then debated how much habitat was needed to support these species. After three years of discourse the team delivered the San Francisco Bay's first regionwide restoration goal in 1999, one that 20 years before would have seemed fantastical to those early Muzzi Marsh trailblazers: 100,000 total acres of tidal wetlands — nearly half of what had been lost to 150 years of human development.

Supersized Restoration in an Era of Climate Change

With the purchase of the 10,000-acre Napa River Salt Ponds — financed with oil spill mitigation funds — the restoration community began to shift its focus from individual "postage-stamp" mitigation projects to the idea of large-scale restoration. Since the year 2000, restoration efforts have rapidly jumped up in size, complexity, and ambition, with projects like Hamilton Airfield (648 acres), Sears Point (960 acres), Bel Marin Keys (1,900 acres; see also p. 37), Montezuma (2,300 acres), and the South Bay Salt Ponds (15,100 acres; see p.33). With this came a recognition of the massive benefits of restoring landscape-scale ecological functions, though those benefits came with new challenges — not the least of which include looming climate change.

In early 2006 an excavator near Alviso, San Jose's waterfront district, dug a narrow trench to breach the blandly named Pond A19, reconnecting 800 acres of former industrial salt ponds back to the Bay. The broken berm ushered in the tides, and with it one of the largest tidal restoration projects ever undertaken: a 50-year reestablishment of wetlands across an area half the size of San Francisco. "The scale really amazes me now," says Siegel. "In the 1970s and '80s, restoration projects were little things. Today the larger scale has really changed what can be accomplished."

In addition to their size, these "third-generation" projects have taken a more holistic view, recognizing the importance of including upland transition zones and subtidal habitats in wetland restoration, instead of focusing only on marsh. Incorporating habitat features like oyster beds and eelgrass for wave attenuation into flood infrastructure, and water filtration and marsh mounds into habitat restoration, has given rise to multi-benefit projects that blur the boundary between nature and infrastructure.

As the scale of projects has increased, so too has the available science and analytics. Now there are streams of satellite and drone data to monitor everything from salinity and elevation to vegetation cover and species observation. The South Bay Salt Pond Restoration Project has a full-fledged science program tracking 26 indicators ranging from breeding success of avocets and harbor seals to public access and water quality (see p. 33). The project is mapping habitat evolution from space at a half-meter resolution. There is now a new Bay-wide wetland monitoring program specifically focused on assessing restoration progress on a larger scale.

Nowadays restorationists have the online-dating-inspired SediMatch tool to connect dredge sediment donors with matching restoration project recipients. They can capture ambient DNA molecules from a scoop of water to determine presence of the most cryptic species. A glance at the last Bay-Delta Science Conference shows researchers using artificial intelligence to inform Bay-wide water flow models, carbon and nitrogen isotope analysis in sandpipers, and a pilot attempt to create floating wetlands.

This flood of data, tools, and knowledge is critically important as climate change challenges wetland restoration to continue evolving. For example, sea-level rise means those hard-earned lessons of under-filling restoration sites may not apply anymore, and banking "elevation capital" is needed in some areas to help habitat keep pace with rising waters. Instead of a hard target for acres of marsh habitat restored, the South Bay Salt Pond Restoration Project developed a 143-page, 50-year adaptation plan for how to monitor and iterate data into management decision-trees as the restoration, and climate change, unfold.

"I'm most excited about collaborating with other scientists working on the shared goal of tackling the climate change issues ahead of us," says Ball, who is working on the regional wetland monitoring initiative. "Technology will continue to advance — and I think we are ready to embrace it."

It's been a long journey since the era of orange peels and sticks in the mud. We've added nearly 18,000 acres of wetlands to the some 40,000 acres of remnant marsh that were protected from development. With tens of thousands more acres in the restoration pipeline, we are inching closer to that once-inconceivable goal of 100,000 acres of wetlands. Perhaps even more impressive than the scientific advancement is the funding landscape: today there are multiple federal and state pots for wetland restoration, and dedicated Measure AA funding available after years of tireless advocacy by Bay conservation groups.

GPS and use of airboats help restoration crews target native ecotone plantings in hard to access interior wetland sites. Photo: Simon Gunner

Almost 45 years after the Muzzi Marsh experiment, the wetland restoration community is now flush with funding and public support, and spurred on by exciting advancements in restoration science and small but important steps by regulatory agencies to speed up project permitting. By any measure, it appears the wetland restoration community is no longer stuck in the mud.

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D E L T A

New Baseline for Habitat Gain

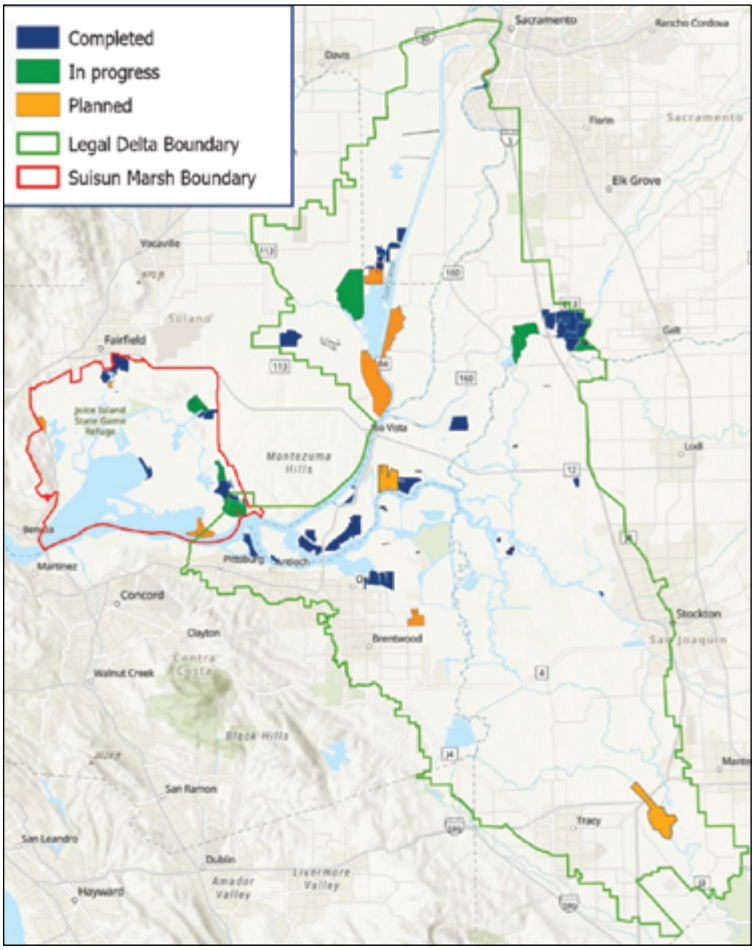
CARIAD HAYES THRONSON, REPORTER

When the Delta Stewardship Council amended its Delta Plan and established a goal of restoring 60,000 to 80,000 acres of wetland above a 2007 baseline by 2050, it raised some fundamental questions: How much of that goal has already been met, and where? A recent study, presented at the Delta Plan Interagency Implementation Committee Restoration Subcommittee's first-ever Delta Restoration Forum in February, provides some answers.

The amendments to Chapter Four of the Delta Plan, which focuses on protecting, restoring, and enhancing the Delta ecosystem, synthesized 14 existing agency reports and other documents in establishing the 2050 targets, which are deemed necessary to achieve the larger goal of restoring a functioning ecosystem by the end of this century. However, "there wasn't an up-to-date accounting of how much restoration had been completed," says the Delta Stewardship Council's Dylan Chapple, who presented the findings of the draft ecosystem restoration progress report at the forum. "Our work is the first time that those numbers are being compiled across different projects and programs and then using it to assess how far along we are towards those policy goals."

The new report defines "restoration" as projects that result in a net gain of habitat. "It has to have quantifiable acreage," says Chapple. Invasive species control, preservation and conservation projects, and the like are not included.

According to the findings of Chapple's team, tidal wetlands have seen by far the most restoration gains, with roughly 9,650 acres completed or in progress since 2007, and an additional 4,737 acres planned, out of a 32,500-acre target. Riparian and floodplain restoration has the furthest to go, with just 1,677 acres of the 16,300-acre target met, and an additional 856 acres planned.



Source: Delta Stewardship Council

"There will certainly be challenges with the achievement of these targets," says Chapple, citing land-use conflicts as one of the reasons restoration in the Delta has been slower than in the lower Estuary. Elevation is another big issue, "especially with our tidal wetland restoration goals. There's a finite amount of land that is at appropriate intertidal elevation to create tidal wetland habitat."

Nevertheless, says Chapple, the pace of restoration in the Delta has accelerated in the last five years. "It's a really exciting time to be working on restoration in the Delta, because a lot of large-scale projects that have in some cases been planned since the late '90s are finally reaching completion through the hard work of hundreds of people over the years who have given their blood, sweat, and tears to making these really challenging projects happen," he says, pointing to Dutch Slough as an example. However, he also notes that climate change and sea-level rise mean there is no time to waste.

Another finding of the study points to potential challenges going forward. The largest single driver of restoration has been mitigation required by Biological Opinions for Delta smelt and salmon under the 2010 Fish Restoration Program Agreement between the California Department of Fish and Wildlife and the Department of Water Resources, which called for the restoration of 8,000 acres of intertidal and subtotal habitat. "This this has been effective in the near term, but looking ahead, it's unclear what more mitigation will be required," says Chapple.

Chapple believes that events such as the Delta Restoration Forum will be critical to achieving the Delta Plan's targets. The forum brought together more than 100 scientists, planners, and stakeholders to discuss programs, projects, and funding opportunities. "I can't overstate the importance of bringing people together for these complex projects because communication and coordination are so key, and there are so many great people that are really dedicated to this process." Chapple says the Interagency Implementation Committee hopes to hold similar forums about twice a year. "A lot of what we see as the next steps from this review effort is just providing the space to strategize around the longer-term achievement of these goals."

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WILDLIFE

Wetland Restoration Is for the Birds

JANET BYRON, REPORTER

It's high tide at Eden Landing Ecological Reserve, on San Francisco Bay due west of Union City, and Nathan Van Schmidt is counting birds on Pond E9 with both hands. Van Schmidt, science director for the San Francisco Bay Bird Observatory, has a clicker in his right hand to track American Avocet, and another in his left for Northern Shoveler. "Wetlands can support an incredible biomass of birds," he says. "And Eden Landing is one of the birdiest places in the Bay."

The Observatory, a local nonprofit bird conservation organization, helps the South Bay Salt Pond Restoration Project to monitor how birds are doing on 82 managed ponds and restored tidal wetlands. This pond, with water levels maintained at about a foot, is perfect foraging habitat for larger shorebirds and dabbling ducks like the ones Van Schmidt is counting. But you won't find small, migratory shorebirds such as the threatened Western Snowy Plover on Pond E9; they're much more likely be spotted on Pond E14, which the restoration consortium manages as a mudflat with lots of oyster shells spread on the ground to provide camouflage from predators for the teeny-tiny white-and-brown birds.

Small shorebirds prefer mudflats, Van Schmidt explains, while dabbling ducks and larger waterbirds need shallow ponds, and diving ducks and large waterbirds thrive in deeper ponds. Tidal wetlands can support different species depending on how high the tide is. "It's a balancing act," he says. "Which bird species will have more habitat in which type of wetlands restoration? We don't know the answers to these questions. That's why we're out here monitoring."

A Bright Spot for Birds

The San Francisco Bay and Delta are critically important for millions of birds, with a million or so stopping to rest, refuel, and breed as they migrate north or south along the 10,000-mile Pacific Flyway. For millennia, indigenous Ohlone people hunted at the edges of the Bay for abundant waterfowl, using nets and traps. When European immigrants arrived in the Bay Area, they marveled at the massive numbers of waterfowl that reportedly blackened the sky when flocks took flight. By the mid-20th century, 80% to 90% of the Bay Area's tidal marsh had been drained and repurposed, and populations of migratory and resident birds that rely on wetland habitat declined precipitously.

Across North America, bird populations have been in freefall since the mid-19th century due to habitat loss, overhunting, and environmental degradation. An October 2019 study in *Science* estimated that 3 billion birds have been "lost" in the United States and Canada since 1970, representing a 29% decline in their overall abundance. "We're missing 3 billion birds, and I don't know where we're going to find them," says Steve Beissinger, UC Berkeley professor of conservation biology. "But the one group that's doing better is the wetland birds. Their decline has slowed down."

Wetlands habitat is undoubtedly making a slow comeback around the Bay. In its 2019 State of the Estuary Report, the San Francisco Estuary Partnership found that the status of tidal marsh ecosystem — a key indicator of estuary health, and essential habitat for waterbirds like ducks and shorebirds — is trending upward. "Tidal marsh restoration is proceeding at a brisk pace in the Bay and gaining traction in the Delta," wrote Letitia Grenier, the partnership's lead scientist.

Restoring tidal action to former wetland areas invariably means more birds, Beissinger says. "In the Bay, when we recreate wetlands where they used to be, there's a good chance that they're going to be used. If you follow the water, you start to see which conditions are attractive for birds."

Constructing Intentional Wetlands

Research conducted in Beissinger's lab at UC Berkeley — where Van Schmidt did his doctoral work — followed the water and found that the secretive, state-endangered California Black Rail was successfully (and amazingly) breeding in artificial wetlands that were created intentionally or accidentally by leaky irrigation pipes, all over the foothills of the Central Valley.

Across the Bay and Delta, water and wildlife agencies — in partnership with bird advocacy organizations — have spent the past few decades restoring and recreating wetlands to provide bird

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Left: Shorebirds on restored habitat. Photo: William Chan, USGS. Right: Nathan Van Schmidt monitors birds. Photo: Janet Byron

Left: Boat launch at Eden Landing. Right: Eden Landing maintains critial habitat for the threatened Western Snowy Plover. Photos: Janet Byron.

habitat and protect threatened and endangered species such as the Western Snowy Plover, Ridgway's Rail, Giant Garter Snake, and Salt-marsh Harvest Mouse. Some new wetlands are created by breaching levees and restoring tidal flows, while others are made by adding water to former salt ponds at different levels.

Beginning in the mid-19th century, more than 50,000 acres of wetlands around the Bay were drained to create huge flats for drying out salty brine. A century later, Cargill — owner of the ponds — donated or sold more than 40,000 acres for wetlands restoration, which were transformed into the Don Edwards San Francisco Bay National Wildlife Refuge (1979), Napa-Sonoma Marshes Wildlife Area (1994 and 2003), and South Bay Salt Pond Restoration Project (2003). (Cargill still harvests salt from more than 12,000 acres around the Bay.)

The South Bay project is managed by a consortium of federal and state agencies and nonprofit organizations, led by the U.S. Fish and Wildlife Service and California Department of Fish and Wildlife. Their aim is to restore 50% to 90% of 15,100 acres of former South Bay salt evaporation ponds to tidal marsh over the next 50 years. (See also p. 33.)

Tweaking Bird Habitat

Researchers from the San Francisco Bay Bird Observatory are out monitoring birds at the South Bay Salt Pond Restoration Project five days a week, and they visit each pond at least once every six weeks. After counting the birds, Van Schmidt takes note of cloud cover and measures air temperature and other environmental factors. He uses a handheld sonde instrument to monitor the pond's water level, salinity, pH, and dissolved oxygen.

Scientists like Van Schmidt have come to understand that there are bird winners and bird losers when full tidal action is restored to salt ponds. A 2002 study by Point Blue Conservation Science (then known as Point Reyes Bird Observatory), U.S. Geological Survey, and San Francisco Bay Bird Observatory showed that the Bay's salt ponds were supporting 75 waterbird species, which added up to more than a million birds at high tide. "Restoring salt ponds to tidal marsh should proceed with caution to avoid loss of waterbird diversity and numbers in San Francisco Bay," the researchers warned.

"We're taking years of data collected in North and South Bay salt ponds, evaluating it for how birds are responding to habitat changes that have already happened, and using that information to support wetland restorations and management in the future," says Susan De La Cruz, research wildlife biologist with the Geological Survey's Western Ecological Research Center in San Francisco Bay. "We're doing a lot of studies about tweaking managed ponds. Once you breach a habitat, it's much less of a controlled environment."

Because two-thirds of the salt ponds in the Napa-Sonoma Marshes Wildlife Area have already been restored to tidal action, research conducted in the North Bay has been invaluable for managing ponds and restoring tidal marsh in the South Bay. To improve the suitability of this new habitat for waterbirds, land managers are adjusting the depths and salinity of the managed ponds there and constructing islands and berms to create breeding and roosting areas that meet the needs of different birds. "Conditions are getting better for the birds in managed ponds," De La Cruz says. "They are more able to support a wide variety of birds because of salinity and management changes."

Restoring Tidal Action to the Delta

At the same time that tidal wetlands around the Bay were being drained, a vast network of levees was being constructed across some 400,000 acres of the Delta to manage water supplies and create farmland. Left with only scattered patches of wetlands, primarily in Suisun Marsh and the western Delta, migratory and resident birds in the Delta and Central Valley now rely on managed seasonal wetlands, flooded rice fields, and harvested corn for food supplies.

The Delta Plan is a state-mandated strategy to maintain reliable water supplies for urban and agricultural uses, while restoring Delta ecosystems. An overarching goal is to "restore habitat necessary to avoid a net loss of migratory bird habitat and, where feasible, increase migratory bird habitat to promote viable populations of migratory birds."

Chapter 4 of the plan establishes the long-term goal of restoring tidal flows to about 10% of the Delta and Suisun Marsh, about 60,000 to 80,000 acres. In addition, the plan sets goals for the restoration of riparian and nontidal wetlands, which are also important for birds. Likewise, California EcoRestore, a multiagency project led by the California Department of Water Resources, aims to restore 30,000 acres of tidal marsh habitat in the Central Valley and Delta (see also p. 8).

But these big goals still need to be translated into specific restoration plans that include consideration of bird habitat needs, says Julian Wood, San Francisco Bay program leader for Point Blue. "On the planning side, we need to set more-specific bird conservation objectives for the Delta, similar to what the Central Valley Joint Venture has done for the whole valley. We need to strategically locate restoration efforts in places that will expand on areas that are already really valuable for birds."

To that end, Point Blue is identifying "Priority Bird Conservation Areas" in the Delta to help land managers and planners support conservation and adaptation actions that provide benefits for multiple species of birds, says Kristen Dybala, Point Blue's principal ecologist for the Pacific Coast and Central Valley.

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SACRAMENTO RIVER

Planning for Setbacks and Swallows

DANIEL MCGLYNN, REPORTER

Adam Henderson spreads out an atlas with colorful pages on the closed trunk of his white sedan. It's an early morning in February and the sun is just high enough to start burning off a blanket of fog that's settled among the nearby willows and cottonwoods. Behind us, across a gravel parking lot, is a gate that's an access point for the Sacramento River National Wildlife Refuge, controlled and maintained by the U.S. Fish and Wildlife Service. On the other side of the gate, a couple hundred yards of flat field ends in a 20-foot drop that acts like a well-defined shoulder for the river—and it's the reason why we are standing here. Thanks to January's heavy rains, the river has reworked the bank, creating a fresh surface for threatened bank swallows (known scientifically as Riparia riparia) to build burrows when they arrive from Mexico later this spring.

The bank swallows are disappearing from the Sacramento River region, one of their most important nesting and breeding grounds in North America. And while this story is about the bank swallows, it's also about what can be done to prevent them from vanishing altogether. For the bank swallows to maintain a healthy population—along with 15 other critical species in the region identified by the Central Valley Flood Protection Plan Conservation Strategy, updated in November 2022—it will take more restoration of river processes and native riparian habitat. And the key to more restoration along the Sacramento River is to combine large-scale habitat projects with flood-control projects, particularly projects that give the river room to wander and meander and swell in the unpredictable times ahead.

Henderson is a senior environmental scientist for the California Department of Water Resources. He's spent the last 25 years exploring and studying the river—including working with a team on annual counts of bank swallow colonies. His focal point is the reach of the Middle Sacramento River between Red Bluff and Colusa. This stretch has a lot of needs, including public safety, ecosystems, and working landscapes, he says: "The goal is to try to find balance between all those interests in the same footprint."

Like their name implies, bank swallows build burrows in the sides of the Sacramento River's sandy banks. Photo David Bogener

The atlas Henderson is thumbing through, the Sacramento River Geomorphic Atlas (1896-2012)—and occasionally referencing pages that show the spot we are standing on from different perspectives—tells the story of how the Sacramento River has changed over time. When left alone, that's what rivers do. They braid and wind and move as they respond to everything from seasonal whims like water flows to more enduring traits, like the geology of the channel. One of the pages Henderson wants to show me is a view of all of the revetment in the area.

Overlooking the Sacramento River near the Pine Creek Unit parking lot. The Highway 32 bridge is visible. Photo: Daniel McGlynn

Revetment refers to rocks and rubble that are placed along the river's banks to act as a kind of armor, with the aim of slowing erosion or keeping the river on a predictable path. The issue with this strategy is that if enough of a river is armored, then it stops being a river and starts to act more like a gigantic culvert: a ditch delivering water from one part of the state to the other. As Henderson describes it, "It disconnects a river from its floodplain."

The other issue is that California's topography and climate act in such a way that the river, and the native plants and animals that rely on it for feeding, forage, and shelter, are adapted to the Sacramento's see-saw dynamics of seasonal high and low water. The historical and ecological variability of the river's flows, fed by dozens of tributaries that run out to the San Francisco Estuary, has created cyclical opportunities for wildlife to grow and reproduce. Runs of spawning salmon are one example. And re-groomed river banks for swallows to burrow and build nests is another.

"The bank swallow serves as a keystone species," says Ron Melcer, who studied the Sacramento River's population as a PhD student at UC Davis and now oversees the California State Parks Wildlife Program. "There is no way to put a bird box up to protect this species. You need to provide its real natural habitat, which is actually a river interacting with the floodplain."

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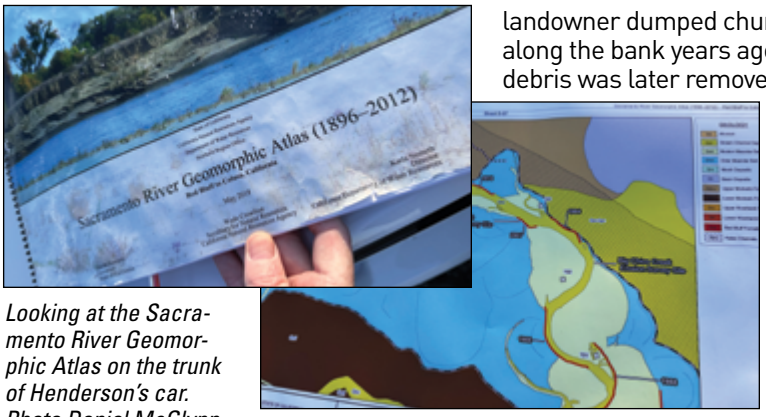

Looking at the Sacramento River Geomorphic Atlas on the trunk of Henderson's car. Photo Daniel McGlynn.

Bank swallows are small brown songbirds with a double-chirp call that can sound almost mechanical, like when a wheel spins rhythmically but noisily on rusty bearings. They have a distinctive white, collar-like mark around their neck and live out in the open and along waterways, relying on eroding river and stream banks to create optimal conditions to dig deep tunnels (up to a foot-and-a-half in depth) that they excavate with their beak, feet, and wings. Males will dig the burrows in the early spring in hopes of attracting females. The colonies can number anywhere between 3 to 3,000 nearby burrows. They eat while flying — with busy, fluttering flight paths — often feeding on airborne insects.

Bank swallows are found worldwide (in some places called sand martins) and recognized by conservation groups as a common species in sharp decline. In California, the state recognizes the bank swallow as a threatened species, but so far there are no federal protections for the birds. In the United States, the two big populations of bank swallows are in the Great Lakes region and along the Sacramento River.

One reason for the steep decline in their numbers is the steady loss of those eroding river and stream banks where they make nests and build colonies. When that habitat disappears, so do the bank swallows. According to some of Melcer's research, the bank swallows also respond when their habitat improves, or when it's restored. "Of the18 locations along the river where the rock was removed, either deliberately or because it was washed away, the swallows have come back in all but two," Melcer says. "And they come back fast, like in one-in-a-half to two years."

One site where Henderson points out the revetment on the atlas, and then walks me out to the river to see remnants of the rubble, is a place where a landowner dumped chunks of concrete along the bank years ago. Most of the debris was later removed, but a few pieces remain out in the river's channel, acting like a reef. "There's not a whole lot of new public rock going in these days," Henderson says.

In decades past, armoring riverbanks with revetment used to be common practice—even among conservation groups thinking it would help with habitat protection. The Flood Control Act of 1960, for example, created the Sacramento River Bank Protection Project, which gave the U.S. Army Corps of Engineers, along with other agencies, the mandate to look for places to rock river banks as a means of flood protection.

But now, because of a better understanding of how the Sacramento River works as a system—and how constant erosion and deposition is an important ecological function providing specialized niches for local species—adding revetment to river banks is not as popular. Increasingly, any kind of new flood-protection measure is pushed farther back from where the river runs today, in hopes of allowing the dynamic processes created by the river to unfold. At least that's the case on the Middle Sacramento, where there is room for things like setback flood protection. Downriver, because of increased population density, it's a different story.

"Usually, we think of rivers getting wider as they move downstream, but the Sacramento River actually gets more constricted," says Henderson. Creating space along the Sacramento River is a major theme of the Central Valley Flood Protection Board's plan, which identifies flooding as one of the biggest public-safety issues facing residents of the Central Valley. Concerns about a future defined by unpredictable and heavy, wet storms increasing flood risk is a dominant message throughout the plan, which was mandated by the 2008 Central Valley Flood Protection Act and just updated in December 2022.

"We will see things we have never seen before," says Tim Ramirez, one of the flood board members. "It's hard to move the [flood control] infrastructure, but in some cases we have room. Where we have room, the more infrastructure we can move back the better. More space will help us address uncertainty, because you can't get space back."

Making more space is a major theme that comes up along the Sacramento River's 447-mile course. The river has been engineered and hardened to protect against flooding. But all of the tinkering on its banks have come at a cost to native species and the natural dynamics of the river. Until recently, it was hard to quantify those losses with respect to flood control. Or maybe put another way, it was really hard to pay for habitat restoration when there was so much flood control work to do. But now, in part because of some successful projects over the years on the Middle Sacramento, there is a model that shows how the return on investment of restoring river processes and their associated habitats while modernizing flood protection can address the dual threats of erratic river behavior and loss of native species across the region.

The Proving Ground

There's a bridge just upriver of the bank swallow habitat I visited with Henderson that connects the small town of Hamilton City to nearby Chico via Highway 32. Immediately north of the bridge a cluster of newly placed big rocks protects its footing adjacent to a wide field covered in grass stubble. Rimming the field is a rise topped with a gravel road — a new levee pushed back from the river's edge. Construction of the setback levee was completed in 2021, replacing an old levee that more closely hugged the bank of the river and creating 400 acres of new habitat now slated for restoration.

The newly created field and levee are components of the larger Hamilton City Flood Risk Reduction and Ecosystem Restoration Project. The community drove the project from the ground up, over 20 years, mainly because the city's size and overall economics made a project of this scope easy to overlook. For years, residents' pleas for more flood control went unanswered.

"Hamilton City is one of those places where it was difficult to use the traditional process to document who the beneficiaries were to be

able to do the obvious things," says Ramirez. That's one of the reasons why the project is so unique and will result in 6.8 miles of new setback levee and 1,361 acres of restored riparian habitat area. Over the next year, this grass stubble field will be replanted with native riparian plants.

I met with Ryan Luster, senior project director for The Nature Conservancy, just downriver at the other end of the new levee. We are standing on the shoulder of Road 23, on top of the levee, right near another wildlife refuge parking lot. Looking north, the levee jaunts away from the river, which is just out of sight, behind clusters of trees. The east side of the levee, like most of the land nearby, is studded with the tidy rows of a working orchard — plum, walnut, and almonds are common crops around here. A pristine-looking gravel road tops the levee, which creates a pronounced ten-foot rise across otherwise flat fields. The levee here is lower than it is north of Hamilton City, where it has more of a job to do in terms of flood control. Here the "training levee," as Luster calls it, protects agricultural land by slowing down high-water events.

To our west — the river side of the levee — there are two different parcels that are part of the restoration work happening in the former orchard land that lies between the river and the new setback levee. The parcels are transected by Road 23; one of them was planted in 2007 (before the new levee was built but with its future path in mind), and the other was planted in 2017.

Between the three restoration sites — the grass stubble by the bridge, the beginnings of a new riparian forest on property owned by a new local reclamation district on one side of the road, and then a more mature and well-established riparian forest restoration that is part of land managed as part of the wildlife refuge — a picture starts to emerge.

The north side of the Highway 32 bridge right outside of Hamilton City. The bank near the bridge footing is protected by rock. Photo Daniel McGlynn

The south end of the new setback levee, with an orchard on one side of the levee and newly restored riparian habitat on the other. Photo Daniel McGlynn

Ecological ROI

For years, Luster explains, The Nature Conservancy purchased land up and down the river and then restored it back to its riparian roots. But the Hamilton City project is different because of the scale of the project, both in terms of time and because of the amount of resources involved. Another thing that makes the project so different is how the community was able to pay for it all.

Hamilton City has a population of about 2,500 and sits at the intersections of Highway 32 and Highway 45, in Glenn County, which is also sparsely populated. The community, and the old levee that surrounded it, were first built in 1905 by James Hamilton, who had a sugar beet empire in the Central Valley. Vestiges of the sugar beet operation still exist, like a processing plant tower that serves as a benchmark in an otherwise tabletop flat landscape. After the sugar beet bust, the dominant economy became orchard crops. Hamilton City never grew much beyond several square blocks established during its company town days.

The threat of flood is persistent in Hamilton City. Residents evacuated six times in the last 30 years due to high-water threats, and instances of flood fighting are fairly routine. The town's levee system, named on historic maps as "J Levee," was privately owned. Maintaining it was never officially the responsibility of any local, state, or federal government. For years, the community asked for better flood protection. And for years, a new flood-control infrastructure project built by the U.S. Army Corps of Engineers (they are the chief levee builder along the Sacramento River and elsewhere) wouldn't pencil out.

To put it simply, protecting the town's value (in terms of property) didn't justify the expense of building a new levee. It was more cost-effective to just fight floods when needed. In 2000, the return-on-investment calculation changed, however, when Congress acknowledged that the eco-

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Looking north from the Highway 32 bridge. The middle section, between the levee and the river, is slated for habitat restoration. Photo Daniel McGlynn

A view of the new setback levee from Road 23. Photo by Daniel McGlynn

nomic benefits of ecological restoration could factor into new flood-control projects built by the Corps of Engineers.

The Hamilton City Flood Risk Reduction and Ecosystem Restoration Project is a perfect example (and the first in the nation) of how viewing flood control more holistically can have multiple benefits. "The key to this whole project was the cost-benefit ratio," says Luster. "For years and years, just building a new levee wasn't economically justified, but then once we could add in the habitat benefits, it worked. Basically, 90% of the project benefits are ecosystem benefits, and those ecosystem benefits are what pay for the new setback levee."

On paper, project planners could show that a new levee setback from the river channel—leaving wide swaths for habitat restoration—could create more space for the Sacramento River to meander, reduce flood risk to Hamilton City, and allow more room for the region's native plant and animal species to recover from decades of habitat loss. "The Army Corps of Engineers brought in the U.S. Fish and Wildlife Service to put a dollar amount on the 1,400 acres of the restored habitat," Luster explains.

One of the biggest issues facing the project was that there wasn't an official "non-federal partner." Levees, flood protection, and habitat restoration all take money to maintain and function properly, so the big question for the residents of Hamilton City was who would take care of a big new project once built? The state and the county (typical candidates for non-federal partners) were reluctant to take on more flood-related liability. So the project proponents involved in the early days of the process started consulting with lawyers and figured out that under state law, the community could create a new kind of local-government entity called a reclamation district. Voters approved Reclamation District 2140 in 2005 to start working on flood-control issues around Hamilton City, with the sole purpose of becoming the non-federal sponsor for the project.

Better flood control was so important to Hamilton City's residents that even before Congress approved the project, the new reclamation district, again with voter approval, started taxing residents and businesses. The tax, which now helps pay for levee maintenance is proportional to flood-control benefits received by each taxpayer (big landowners pay more than someone who owns a house in town).

J-Levee map. Courtesy Reclamation District 2140

Meanwhile, The Nature Conservancy worked with the community and local landowners to buy property where the future Hamilton City project would be situated. Eventually, the nonprofit turned the land over to the newly formed reclamation district, which was able to use the value of the land as Hamilton City's monetary contribution to the project as the non-federal sponsor.

After delays because of national politics, the economic crisis of 2008, and other setbacks, construction of the Hamilton City project finally got underway in 2016. The first fully restored spot is where I stood with Luster next to Road 23. "The way we describe the project, it's the first multi-benefit project designed by the Army Corps in the United States. From the very beginning, this was a habitat-restoration and a flood-risk-reduction project," Luster says. "We wanted this to be a model for the Army Corps nationally, and in California, particularly in the Central Valley, where everyone realizes that we needed a different approach to flood-risk reduction and habitat restoration."

Around the Bend

Back when I stood on the big bank overlooking the river with Henderson, he explained what things look like during times of drought and during peak water events. And he described the scene when the bank swallows return in full burrow-building mode. There could be hundreds of birds swooping and swinging right along the river where we stood.

But despite all the evidence, and despite his help, I still couldn't visualize it. As I read the descriptions and forecasts in the latest update of the Central Valley Flood Protection Plan, I had a similar problem. Models depicting greater warm-weather storms, more flooding, and more intense and prolonged strings of drought seem almost incomprehensible. All of the outcomes feel fuzzy despite the stories of the historic record and the scientific evidence showing that the region's weather will only become more erratic.

And maybe that's the biggest lesson learned from the Middle Sacramento River. Preparing for the future is not only about restoring the natural processes and creating habitat for a threatened species, or re-situating levees and rethinking armored banks. It's also about getting ready for a future we can't quite comprehend yet. That might be the biggest challenge — but it also provides the greatest opportunities for imagining large-scale, ecologically-based infrastructure.

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CLEAR LAKE

Saving a Species Struck by Systemic Oversights

JEANINE PFEIFFER, REPORTER

Since the 1950s, four native fish extinctions have taken place in Lake County's Clear Lake: the thicktail chub, Clear Lake splittail, Pacific lamprey, and hardhead. A fifth endemic species, the Clear Lake hitch, is teetering on the brink.

"Agencies view the hitch as just a fish. But for Tribes the hitch is sacred," explains Big Valley Band of Pomo Indians tribal elder Ron Montez, Sr. "We believe Creator placed this fish here to help us survive for thousands of years. The chi (Pomo word for hitch) not only fed the seven Tribes around the lake, but it fed Tribes who came in from surrounding counties — Sonoma, Napa, Sacramento — and sustained all these people since time immemorial. That's gone now. Anyone younger than 30 doesn't know anything about this."

Although hitch are equally essential and culturally significant to lakeside Tribes as salmon are to Pacific Northwest First Nations, few people know of their existence. But a recent series of alarming monitoring results, emergency meetings, interventions from Tribes, and unprecedented interagency coordination is now shining a spotlight on the 13-inch-long species and efforts to resolve conflicts over the restorative flows it needs to survive.

During a visit to the top of Cobb Mountain in southern Lake County — one source of Clear Lake's headwaters — leaders of the Cobb Watershed Education and Restoration Project witnessed robust creek flows for the first ten miles. After crossing Highway 29, and heading downstream into the Big Valley basin, it was a far different story. Dams, water diversions, streamside wells, and non-functioning fish ladders left the same creeks — Adobe, Cole, and Kelsey, all critical hitch spawning tributaries — dry or with barely a trickle.

Awareness of stream flow impairments resulting in fish kills, desiccated hitch eggs, and lack of fish passage is not new to Lake County residents, Tribes, or government agencies. In 2012, alarmed by the hitch's decline, Clear Lake Pomo tribes partnered with the Center for Biological Diversity to encourage the California Fish and Wildlife Department to take action. In 2014, the California Fish and Game Commission voted unanimously to list the hitch as a threatened species under California's state Endangered Species Act, and the following year, the U.S. Fish and Wildlife Service agreed to study the hitch for potential federal listing under the federal Endangered Species Act.

Small hitch caught during Tribal sampling efforts along Kelsey creek in spring 2022. Photo Credit: Alix Tyler.

As part of that agreement, U.S. Geological Survey scientist Fred Feyrer was tasked with conducting annual fish counts on Clear Lake. His findings stunned Tribal staff: in 2021, he reported witnessing no juvenile recruitment — no surviving hitch babies — for five consecutive years. Last summer, it took Feyrer and Luis Santana, a Robinson Rancheria fish biologist, thirty tries to catch six hitch.

This winter, Feyrer shocked the scientific community again with data demonstrating that every fish species in Clear Lake is undergoing population declines. "To a tee, every one of the fish we're sampling is in dramatic decline," he reported. "What's particularly striking is that this is a suite of fish who have very different life histories and reproduction patterns. So something is going on — factors within the lake are impacting other species."

Given that Clear Lake is one of the world's most polluted lakes, due to legacy mercury and DDD (a precursor to DDT) poisoning and increasingly frequent harmful algal blooms producing cyanotoxins, in retrospect, these findings shouldn't be surprising. And they point to two core facts: saving the hitch will be a complex undertaking, and everything done to save the hitch will likely help save all the other fish, too.

Overcoming Barriers to Fish Passage

Climate change amplifies the challenges wherever agricultural uses interface with critical wildlife habitat, especially during California's ongoing historic drought. The most vexing question for the Clear Lake watershed, which has everyone scratching their heads and scrambling for solu-

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tions, is how to ensure sufficient flow in tributaries to support successful juvenile hitch recruitment.

Scientists recommend a baseline flow of 34 cubic feet per second when the hitch enter creeks to spawn between February and May, followed by a potamodromous (entirely freshwater) migration weeks later, when juveniles and adults make their way back to the lake. Despite recent heavy rains and snowfall, no one is confident that short-term precipitation will be sufficient to keep water flowing in Lake County creeks for the entire spawning season.

In recent standing-room-only meetings held by the Lake County Board of Supervisors to discuss an emergency proclamation for the hitch, vineyard owners proclaimed unified support for the hitch but adamantly denied that their water use had any significant bearing on dried-up creekbeds, desiccated egg masses, or stranded and dead fish documented during prior hitch migrations. Their fears of potential water rights curtailments ultimately resulted in county supervisors removing references in the proclamation to any regulatory steps that would help establish interim or restorative flows to creeks.

Side conversations between Farm Bureau officials and Tribal staff revealed a more complicated story: surprise at the extent of diversions shown in a map created by the State Water Resources Control Board, and anecdotal knowledge of farmers reporting exaggerated water use in order to retain future water rights — "the use it or lose it" practice common to agriculturalists throughout the West, even during drought.

In testimony at the Supervisors' meeting, Haji Warf, a farmer with land bordering Upper Lake waterways, argued for heightened accountability within the farming community. "Hundreds of straws simultaneously sucking out water is going to cause a rapid depletion — that's just common sense," she said. "I support immediately putting meters on all domestic and agricultural wells tapping groundwaters that feed local streams. Both Mendocino and Sonoma counties have some form of well monitoring, even though they don't have an imminent extinction event like we do in Lake County."

Water-use planning and conservation measures in adjacent regions show promise for application in Lake County. Advocates for the hitch point to the success of strict regulatory guidelines along the Russian River in Sonoma County, where, to prevent stranding and mortality of salmonids, water diversions for frost protection are subject to state-approved water demand management programs. "The winegrape industry deserves credit for its actions, and the State Water Board and wildlife agencies deserve credit for bringing the issue forward," wrote Brian Johnson, California director of Trout Unlimited, in a 2016 legal analysis of the Russian River frost protection rule.

In Mendocino County, in response to declining salmon and steelhead populations, 30 vineyards in the Navarro River watershed did the work to attain fish-friendly certification. Hundreds of other vineyards throughout major watersheds in California have done the same, including vineyards along Putah Creek in southeast Lake County. Yet vineyards located along hitch-bearing creeks are noteworthy for their lack of participation in the program and their opposition to restoration programs benefiting migrating fish.

One of the most significant barriers to hitch passage involves a dysfunctional fish ladder and culvert along Kelsey Creek in the Big Valley basin. The restoration of this site would improve riparian habitat for birds and other wildlife, help raise the local water table, and significantly enhance water flows further downstream. Funding for the project, along with all state, federal, and local permits, has been secured. "The project is literally ready to break ground!" says Angela DePalma-Dow, Lake County Water Resources Department Invasive Species Program coordinator. Yet the project remains stalled, due to a single landowner denying access to a key portion of the streambed needed to begin the construction.

New Coalitions Formed to Save the Hitch

"As Pomo people we were placed in this area, and provided for with everything we needed to live: an abundance of waterfowl, plants, berries, acorns, wildlife. Our relationship with the hitch is one of them sacrificing their lives to help us survive. To honor their sacrifice, we have a call to protect and watch over them," said Tribal member Ron Montez, Sr. during testimony about the hitch emergency at a 2022 California Fish and Game Commission meeting.

LEFT: Volunteers plant sedge grass, a native species used in Pomo basketry, along the banks of Kelsey Creek at Mandala Springs Wellness Retreat, a participant in the Cobb Watershed Education and Restoration Project. Photo: Ron Montez, Sr. CENTER: Hitch stranding and fish kill in Adobe Creek in Spring 2019. Photo: Sarah Ryan. RIGHT: Ron Montez, Sr., Tribal Historic Preservation Officer for the Big Valley Band of Pomo Indians inspects Adobe Creek, a key spawning tributary for the Clear Lake hitch. Photo: Jeanine Pfeiffer

Tribal staff and consultants inspect a non-functioning fish ladder and culverts along Adobe Creek where a restoration project is stalled. Photo: Jeanine Pfeiffer.

Mr. Montez' testimony — which had most of the audience in tears — resulted in a historic first: the Commissioners pledged to bring together three state agencies (the State Water Resources Control Board, the Department of Water Resources, and the Department of Fish and Wildlife), one federal agency (the Fish and Wildlife Service), and multiple county departments to a December summit at the Big Valley Rancheria to compare notes, lay their cards on the table, and develop an action plan to save the hitch.

At the summit, it became apparent to participating Tribal staff that no state or county agency has comprehensively monitored water use in Lake County, or effectively responded to complaints of illegal diversions or overuse. "Your enforcement system is broken," asserted Sarah Ryan, environmental director for the Big Valley Band of Pomo Indians, referring to 2009-2014 data from the Lake County District Attorney's office showing that only 13% of streambed violations within the Big Valley basin — the ancestral territory of both the Tribe and the hitch — had resulted in corrective actions.

In response to these findings and others, including Feyrer's data sets, state agencies rapidly mobilized to assemble more complete water use data sets and provide additional resources for restoration, monitoring, and enforcement. In addition to Lake County's passage of the emergency proclamation, the Fish and Wildlife Department and the UC Davis Tahoe Environmental Research Center established hitch task forces. Three state agencies conducted joint creek monitoring training sessions with Tribal staff, and the State Water Board issued a letter encouraging the agricultural community to adopt voluntary measures including reducing surface-water diversions and groundwater pumping; coordinating irrigation actions with neighbors; filling reservoirs and water tanks earlier in the rainy season; investing in streambed maintenance and restoration; and initiating "pump-back projects" to release water back into the creeks when needed.

Local community-based organizations are also stepping up to help. The Cobb Watershed Education and Restoration Project, an effort that began as an education project, has pivoted to focus on creekside stewardship actions in partnership with Tribes to address connectivity issues that endanger the hitch. Thus far, the project, benefiting from years of relationship-building, has inspired a dozen landowners to overcome concerns about permitting difficulties and agency oversight to initiate restoration measures along upstream tributaries.

"We hope our work can inspire other Clear Lake communities, especially in areas with impaired waterways, to come together with Tribes to save the hitch," said project leader Eliot Hurwitz. "It will take both an ecological and a cultural transformation to create healthy waterscapes that flourish for the long-term benefit of all beings."

Note: Dr. Pfeiffer has worked as a consultant to the Big Valley Band of Pomo Indians on separate water monitoring and cultural preservation projects, but is not directly involved in hitch restoration efforts.

PUTAH CREEK

Reconnecting with the Ocean

ROBIN MEADOWS, REPORTER

After decades of restoration, recent Chinook salmon runs in Putah Creek have reached 1,800, producing young that swim toward the ocean by the tens of thousands. But, says Putah Creek streamkeeper Max Stevenson, this growing population still faces considerable obstacles.

Putah Creek flows from headwaters in the North Coast Ranges to the Toe Drain of the Yolo Bypass, and was dammed near Winters in the 1950s to divert water for Solano County. Salmon began coming to the creek after settlement of a lawsuit in the year 2000 that stipulated releasing water for fish as well as optimizing spawning grounds.

Salmon need loose gravel to dig spawning pits, or redds, that are up to six feet across. "They flop over and slap cobbles as big as six inches with the side of their body," says Stevenson, who the Solano County Water Agency hired almost exactly a year ago as streamkeeper to protect and restore Putah Creek. After spawning, salmon fill the pits back up with gravel to hide their bright-orange eggs from predators.

Dams keep new gravel from tumbling down Putah Creek, and old gravel hardens over time as the space between cobbles fills with fine sediment, forming a thick, cement-like crust on the creek bed. "You can walk on it and not sink in," Stevenson says. To loosen the gravel for salmon, the restoration team "fluffs it up with excavators."

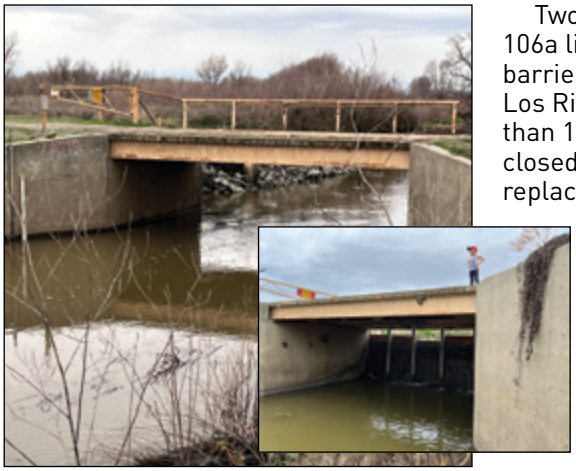
Last year, the team also tried something new. They added 80 tons of gravel below the pedestrian bridge in Winters and were almost immediately rewarded. "There were 15 redds!" Stevenson says. Salmon can lay thousands of eggs in a redd.

Spawning grounds are not enough to support a self-sustaining population of salmon, however. These migratory fish also need unrestricted passage. "You can create gold-star, top of the line, Cadillac salmon habitat but it doesn't matter if they can't get there," Stevenson says. "There's wonderful upstream habitat near Winters, but below I-80 hasn't seen the love yet."

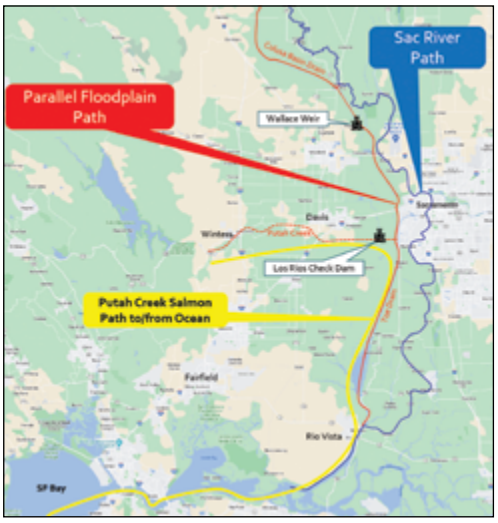
The lower reaches of Putah Creek between I-80 and the Toe Drain are like an obstacle course, sporting several barriers to fish migration. One barrier, a pair of culverts under County Road 106a, has a temporary fix. "The culverts are way too high for salmon to jump," Stevenson says. So the restoration team worked with the farmer who owns the land to install a new fish-friendly culvert.

Stevenson is excited that they used culvert design software, called FishXing, to optimize the size and placement of the new pipe for salmon. From a fish point of view, culverts are trouble when they are out of reach or when water comes through too fast to swim against. The restoration crew embedded the bottom of the new, but temporary, culvert in the stream bed, both making it accessible and slowing the water.

Two miles downstream of Road 106a lies another, more significant barrier to fish passage. This is the Los Rios Check Dam, which is more than 12 feet high and is opened and closed by manually removing and replacing heavy wooden boards. "As soon as the check dam was opened in November last year, 64 salmon shot through the new Road 106a culvert in two hours," Stevenson says. The fish-friendly culvert is something of a bandaid, though, because it could get washed out in the next storm.



Los Rios Check Dam open for fish passage and with boards blocking passage (inset). Photos: Max Stevenson.



For a permanent solution to both barriers, Stevenson envisions creating bypasses to allow year-round fish passage. A 1,600-foot channel around the check dam and a small bridge-like creek crossing for Road 106a would each cost less than $1 million. Stevenson also hopes for a solution to a third salmon barrier: the Lisbon Weir, which is made of rocks and spans the 100-foot width of the Toe Drain.

Stevenson's big dream is to realign Putah Creek below I-80 completely. "The lower third is human-made," he says. "It was dug out in the 1870s to relieve flooding and is a straight as an arrow." Realignment would sidestep all three fish barriers at a cost of $20 to $40 million.

While the restoration team collaborates with many of the private landowners along the creek, sometimes it just doesn't work out. "Landowners worry about ATV trespassing and equipment theft in the park-like areas created by restoration," Stevenson says. "They don't always want to invite that."

Plans for rerouting lower Putah Creek have been drawn up. The beauty is that the bypasses to Lisbon Weir, the Los Rios Check Dam, and Road 106a would all be built entirely on public land, which would simplify the process.

"The ten miles near Winters are great for salmon," Stevenson says. "But these fish have to swim another 100 miles between Putah Creek and the ocean — we need to connect them."

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PERSPECTIVE

Riding the Restoration Waves: My Estuarine Journey

JESSICA DAVENPORT, STATE COASTAL CONSERVANCY AND SAN FRANCISCO BAY RESTORATION AUTHORITY

After 16 years of working in the San Francisco Estuary, including serving as a manager for key regional agencies, I have ridden several waves of restoration. I've seen big changes in how restoration is done, who does it, and who benefits — whether it's a fish or bird on the verge of extinction or a young person from an urban community learning green job skills on the shoreline. Our view of what matters continues to expand as connections that were once cloudy — between habitat restoration and environmental justice, between upland and bay habitats — come into focus. We're not just trying to create small patches of tidal marsh but to piece together a huge mosaic of habitats from working lands to wetlands. We now know that a single project can create new homes for fish and wildlife, protect communities from flooding, and provide much-needed access to nature.

Jessica Davenport

After spending the first decade of my career working internationally on energy efficiency and sustainable agriculture, I have found it rewarding to act locally to address the global challenges we face. While the impacts of climate change and inequities continue to grow, we have unprecedented levels of state and federal funding to do our part to address them. As I look back over the last 16 years of my journey, it feels important to reflect on where we've been and where the next wave of restoration may take us.

Bay Beginnings

When I began working at the San Francisco Bay Conservation and Development Commission (BCDC) in 2007, I was one of seven new staff spread across BCDC's planning, permitting, sediment management, and enforcement divisions. We were lucky to have an infusion of funding that allowed us to be trained in Bay ecology by illustrious experts. We learned about salt marsh harvest mice from Howard Shellhammer, about creeping wild rye and salt marsh pannes from Peter Baye, and about benthic macroinvertebrates and eelgrass from Chela Zabin and Kathy Boyer. We learned about the three Berkeley women who saved the Bay, leading to the creation of Save the Bay and BCDC itself, from BCDC deputy director Steve McAdam, who was one of Save the Bay's first paid employees and later became one of BCDC's first and longest-serving employees.

Corralling Sediment and Breaking the Waves

I was assigned to work in sediment management, issuing permits for dredging projects and participating in the ongoing effort to promote the reuse of dredged sediment in restoration projects, where it was desperately needed to raise the elevations of subsided diked Baylands. By 2007, restoration had already been underway for a couple decades, and practitioners and researchers were constantly seeking to figure out why some projects worked better than others, and apply lessons learned to future restoration project designs. At one point, I helped organize a Wind Wave Workshop, where experts came together to debate the best way to design restoration projects so that waves stirred up by the wind could be dampened, and more suspended sediment could settle out and allow the site to reach marsh plain elevation more quickly, at which point plants could grow. The consensus was that marsh mounds (small islands), pre-cut channels, and ditch blocks were all important design features to include in restoration projects.

Amending the Bay Plan to Address Climate Change

Another highlight of my time at BCDC was participating in the 2011 amendment of the San Francisco Bay Plan to address climate change. One of the major positions of the environmental community was that undeveloped land along the shoreline should be protected from development to reduce the area that would need to be protected by levees as sea level rises and to expand opportunities for habitat restoration.

The Commission eventually adopted a policy that states, "To address the regional adverse impacts of climate change, undeveloped areas that are both vulnerable to future flooding and currently sustain significant habitats or species, or possess conditions that make the areas especially suitable for ecosystem enhancement,

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Mixed cobble, gravel and sand beach at king low tide at Point Pinole. Photo: Marilyn Latta

should be given special consideration for preservation and habitat enhancement and should be encouraged to be used for those purposes." While not prohibiting development, the policy did provide a basis for protecting and enhancing undeveloped areas along the Bay shoreline, many of which have since been purchased from willing sellers and restored or planned for restoration.

Adopting the Delta Plan and Funding the Delta Conservancy

The next leg of my estuarine restoration journey took place a few miles upstream, where I joined the Delta Stewardship Council in 2012 to work on ecosystem restoration, land-use planning, and science integration. I participated in the final stages of developing the Delta Plan, modeled after the Bay Plan. The Council's main contribution to habitat restoration at that time, supported by the Delta Science Program, was to require projects to include adaptive management plans. This requirement was based on an acknowledgement that restoration projects rarely perform exactly as intended, and therefore practitioners need to be vigilant about measuring ecological indicators and making adjustments as needed.

As soon as the Delta Plan was adopted in 2013, it was hit with seven lawsuits filed by 26 parties. Fortunately, the lawsuits were all resolved in the Council's favor in 2020, affirming its authority to help achieve the state's coequal goals of providing a more reliable water supply for California and protecting, restoring, and enhancing the Delta ecosystem, by both restoring habitat and reducing the state's reliance on the Delta for water supply. Still, the legal challenges cast a long shadow over the Council's work for many years. Compared to their counterparts in the Bay Area, local governments, water agencies, and landowners in the Delta saw habitat restoration as a much more threatening proposition.

Another challenge to restoration in the Delta was that the Delta Conservancy, created along with the Delta Stewardship Council by Delta Reform Act of 2009, as "a primary agency to implement ecosystem restoration," did not receive state funding to make grants for several years. Instead, the Delta Conservancy had to apply for grants itself, and focus on convening a long series of meetings to build trust among Delta stakeholders. Eventually, in 2015, the Delta Conservancy received $50 million under Proposition 1, an ecosystem restoration and water quality bond act, to make restoration grants. To date, the Conservancy has approved a total of 29 projects, committing approximately $39.3 million for Proposition 1 grants. More recently, the Amended Budget Act of 2022 provided the Conservancy with $36 million to support restoration, conservation, and climate resilience for wetlands.

The Water Wars

While major habitat restoration projects in the Bay, such as the South Bay Salt Ponds Restoration Project, have proceeded on a voluntary basis, much of the restoration in the Delta is a mitigation requirement, meant to compensate for the ecologically damaging effects of diverting large quantities of water out of the Delta to meet urban and agricultural needs. The "water wars," often framed as "fish versus farms," seem to be never-ending. The Bay Delta Conservation Plan, an eight-year, multi-million-dollar effort to create a grand bargain combining aquatic habitat restoration with construction of 40-mile twin tunnels for water diversion under the Delta, ultimately failed in 2015.

The California Department of Water Resources subsequently divided these efforts into twin proposals: WaterFix, focused on water conveyance, and EcoRestore, focused on habitat restoration. In 2018, the Delta Stewardship Council's staff recommended that the Council find WaterFix inconsistent with the Delta Plan's coequal goals of ecosystem restoration and water supply reliability, and DWR withdrew the proposal. In response to public input on WaterFix in 2018 and guidance from Governor Newsom in 2019, DWR scaled down its proposal from two tunnels to one. DWR's comment period on the draft environmental impact report for the project, now rebranded as the Delta Conveyance Project, just closed in December 2022.

Accelerating Delta Restoration

After a slow start, habitat restoration in the Delta has accelerated over the past few years, as major tidal restoration projects, such as Bradmoor Island, and floodplain expansion efforts, such as the Big Notch Project, have broken ground under the banner of the DWR's EcoRestore initiative. According to DWR, EcoRestore includes more than 30 projects representing an investment of nearly $500 million to date. In addition, long-delayed projects, such as Hill Slough and the first phase of Dutch Slough, finally breached their levees.

Fremont Weir area, part of the Big Notch Project. Photo: Kelly M. Grow, DWR

Eco-apprentices from Literacy for Environmental Justice at Heron's Head Park. Photo: SCC

In addition, the Delta Stewardship Council adopted an Ecosystem Amendment to the Delta Plan in 2022, the culmination of a seven-year collaborative process. This updated chapter of the Delta Plan requires project proponents to explain how their projects are designed to accommodate anticipated sea-level rise and to include this information in an adaptive management plan. It recommends the use of a "Good Neighbor Checklist" to help restoration projects avoid or reduce conflict with existing land uses. And it contains new recommendations regarding the need to fund reversing subsidence, enhancing working landscapes, and improving habitat for juvenile salmon.

Measure AA for the Bay

I watched these developments from afar, however, as I floated back downstream to the Bay in 2016 to work for the State Coastal Conservancy's Bay Area Program. On the heels of the passage of Measure AA in 2016, the Conservancy, in partnership with the San Francisco Estuary Partnership and the Association of Bay Area Governments (which later merged its staff with the Metropolitan Transportation Commission), began ramping up its staffing support for the San Francisco Bay Restoration Authority. Previously operating on a shoestring budget since its creation by the State Legislature in 2008, the Authority began to receive $25 million per year in parcel tax funds ($12 per Bay Area property per year) to support restoration and enhancement of shoreline habitats, starting in 2017.

In its first five years, the San Francisco Bay Restoration Authority awarded more than $125 million generated by Measure AA, and leveraged a further $175 million, to support a broad range of large projects, small-scale pilot projects, and planning and design projects that are improving water quality, climate resilience, wildlife habitat, and public access opportunities at the shoreline in each of the Bay Area's nine counties. The Authority has now funded 36 projects in total.

Bay Restoration: How, Who, and For Whom?

Since I first arrived on the Bay restoration scene in 2007, I've observed significant changes in how restoration is done, who does it, and who benefits. While earlier projects were narrowly focused on restoring tidal marsh, I now see projects that strive to restore a complete marsh ecosystem, including subtidal habitats, mudflats, low marsh, high marsh, and the wetland-upland transition zone. There is a growing focus on supporting increased biodiversity by including uplands and seasonal wetlands, as well as tidal wetlands, in site design. Projects have also evolved from having only ecological goals, with a particular focus on creating habitat for endangered species, to a multi-benefit approach, which involves community engagement, workforce development, flood protection, and public access.

Equity is now front and center, as both the Conservancy and the Authority prioritize projects that expand public access, community engagement, and workforce development in low-income communities of color and improve access for people with disabilities. The Authority has created a Community Grants Program, open only to community-based organization located in economically disadvantaged communities. So far it has provided grants to Marin City Climate Resilience and Health Justice, Literacy for Environmental Justice in San Francisco, and Planting Justice in Oakland. These projects support community engagement in the design of future restoration projects, as well as hands-on restoration work. The Conservancy has also supported many projects that make shoreline trails and other facilities more accessible for people with disabilities.

Advancing Living Shorelines

Addressing current flooding and future sea-level rise is more urgent than ever, as the Legislature recognized when it allocated $175 million to the Conservancy for coastal resilience, including projects that construct living shorelines and other nature-based solutions to flood risk. Both the Conservancy and the Authority are funding several projects where coarse beaches are being used to protect marshes from erosion related to sea-level rise, such as Heron's Head Park in San Francisco and Greenwood Gravel Beach and Tiscornia Marsh in Marin. "Green" restoration is also being integrated into formerly "gray" flood-protection infrastructure like levees and seawalls. Examples include the South

continued on page 43

RESTORATION Almanac 2023

Decades of dedication are adding up, with nearly 300,000 acres of habitat restored or rehabilitated in the San Franciso Estuary. The benefits of this treasure are increasingly visible, thanks to the work of countless wetland lubbers.

Hamilton City Setback Levee and J-Levee
Big Notch
Putah Creek
Yolo Bypass
The Delta
Lookout Slough
Bouldin Island
Vogel Island
Suisun
Bradmoor Island
Blacklock
Dutch Slough
Luco Pond
Hill Slough
Nurse-Denverton Slough
Montezuma Wetlands
Lower Walnut Creek
Pacheco Marsh
Clear Lake
North Bay
San Pablo Bay National Wildlife Refuge
Sonoma Creek Baylands Strategy
Sonoma Baylands
Petaluma River Baylands
Bel Marin Keys Wetlands
Hamilton Wetlands
San Pablo Bay
Corte Madera Reserve
Tiscornia Marsh
Lower Corte Madera Creek
Muzzi Marsh
Greenwood Beach
Bothin Marsh
Eden Landing
Calabazas San Tomas Aquino Creek
Alviso Island Ponds
San Francisquito Creek
Ravenswood
San Francisco Bay
Heron's Head
India Basin
Crissy Field
San Mateo Creek
Colma Creek
South Bay
Pacific Ocean

122° 30 W
122° 0 W
121° 30 W
121° 0 W
39° 30 N
39° 0 N
38° 30 N
38° 0 N
37° 30 N
123° 0 W
123° 30 W

Habitat Projects

- Individual project

Agency

- Sacramento-San Joaquin Delta and Suisun Marsh
- Sacramento-San Joaquin Delta and Suisun Marsh Prop 1
- San Francisco Bay Adaptation
- Joint Venture
- Water Quality Control Board
- California Department of Fish and Wildlife
- Other

Miles
0 10 20 30 40 50

Mapmaker Amber Manfree was inspired by a 1865 US Coast Survey Sketch J map by Bache et al. Projects highlighted are those mentioned in this special Almanac issue.

BOULDIN ISLAND

An Inclusive Vision for Delta Adaptation

MICHAEL ADAMSON, REPORTER

Aerial view of Bouldin Island. Courtesy MWD

Over resistance from local governments and environmental organizations, in 2016 Southern California's Metropolitan Water District purchased five islands in the Sacramento-San Joaquin River Delta. While it wasn't immediately clear what the powerful water agency intended for these islands, the move reminded some Californians of the "Wild West" years of water rights claimed by surreptitious land purchases. Now, years later, it appears the District is making good on that purchase by taking a leading role in Delta restoration efforts.

The Delta Islands Adaptations project, funded through a watershed-restoration grant from the California Department of Fish and Wildlife, has zeroed in on Bouldin Island (the other four islands purchased at the same time were Webb Tract, Bacon Island, Holland Tract, and parts of Chipps Island) as the prime candidate for modeling successful restoration.

To Choose an Island

Situated between Rio Vista and Lodi and traversed by Highway 12, Bouldin Island doesn't stand out much from the surrounding landscape. On a clear day in mid-February when fields lie fallow, puddles and ponds glisten in the sun while flocks of wintering waterfowl pepper the sky. Egrets and herons wade into the shallows and sandhill cranes hop and waggle in their ostentatious courtship dance.

In the five or so minutes it takes to cross the island by car, only a trained eye would notice the environmental challenges it faces. One such eye, Russ Ryan, senior engineer with Metropolitan Water District and Delta Island Adaptations project manager, takes me on a tour of the island. We start by driving up to the northern levee, climbing about twenty feet up a steep dirt road to the levee top. On the other side flows the South Mokelumne River, swollen from the tide and winter storms.

Bouldin Island currently lies between 20 and 25 feet below sea level and is estimated to have lost nearly half a billion cubic feet of land volume in the last 40 years. "The primary concern is to stop or reverse subsidence," explains Brett Milligan, professor of landscape architecture at UC Davis and a leading facilitator during the restoration project's planning process. "The more the land sinks, the more stress it puts on the infrastructure."

Historically, farmers have grown corn and alfalfa on Bouldin's peaty soils. When the peat is drained, it oxidizes, contributing to greenhouse gas emissions and thinning the layer of arable soil so much so that in some places groundwater seeps to the surface. Large swaths of land on the island are already too wet to farm.

Even considering this extreme subsidence, Bouldin's selection from the five as the target wasn't made arbitrarily, but rather through a collaborative process with an iterative feedback loop. "There are two broad ways we did that," Milligan says. The first was a technical advisory committee with representatives from Delta Stewardship Council, California Waterfowl Association, San Francisco Estuary Institute, and indigenous Tribes, among others. The second was a vigorous public process.

The committee established ten objectives for island selection including subsidence reversal, restoration opportunities, and water quality and supply. Members then ranked each island in order of their preferred choice and weighted the importance of each selection objective.

The selection process integrated outside feedback into the committee's recommendations through surveys and a series of public meetings. "We've solicited input throughout the process," says Milligan. "We've found a lot of

alignment between the advisory committee and the public, including support both for ecological restoration and continued agriculture."

In June of last year, the project progressed from selecting an island to developing a mosaic model that best addresses the diverse range of land-use needs, both public and private. The technical advisory committee and public meetings, some with 80-90 attendees, continue to inform progress.

Ryan attributes this feedback-heavy style of decision-making to a leadership change at Metropolitan Water District that prioritizes "innovation, inclusion, collaboration, and partnerships." He points to new instances of cooperation in historically contentious relationships. "Restore the Delta has shown interest in participating in discussions and providing their input to help inform the work we're doing," he says. "We've traditionally always been on the other side of the fence."

He recalls an "a-ha" moment that helped him bring down that fence between the District and Delta advocacy groups. "The thing that joins us is that water quality supports supply reliability, agricultural use, and the Delta environment as a whole," he says. "If we can make a situation that creates better water quality, it is better for everybody."

A Landscape Mosaic

As we tour Bouldin Island, Ryan points out a line of short and stout cylinders. "Look how well they're growing," he says as he admires the tall thickets of tule reed spilling out over the tops. The cylinders house experimental floating wetlands, a research component informing plans for a new mosaic of land-uses for Bouldin. Data gathered on zooplankton populations (fish food) in the containers indicate that floating peat wetlands could be valuable fish habitat while also capturing carbon in a way reminiscent of tidal wetlands of the pre-reclamation Delta.

Ascertaining how best to balance ecological innovation like floating wetlands with demonstrated cultural and economic benefits of agriculture is at the crux of the current phase of Delta Islands Adaptions.

In September of last year, the project team presented six visions of a redesigned Bouldin Island to the technical advisory committee. They ranged from near-term scenarios (5-10 years) emphasizing agricultural production to long-term scenarios (25-50 years) focused on habitat restoration, leveraging climate adaptation incentives to make the transition economically viable.

After a five-month process of advisory and public feedback, the project team settled on one near-term proposal with several potential long-term contingency plans. "I think the most significant change is in the collective acknowledgement that we can't know what the long-term scenario should or could be at this point in time," says Milligan of the most recent developments. "So we moved towards a range of future scenarios: an adaptive playbook based on a set of if-then propositions."

While the plan sets aside 50% of the island for continued agricultural uses, farmers currently practicing dry farming will have to come around to some new techniques and ideas to adapt to an increasingly wetter Delta due to both subsidence and sea-level rise. Corn and alfalfa will have to give way to rice and other wet agriculture on a new Bouldin.

"You would expect pushback," says Ryan about proposing sweeping changes to farmers. But he has found otherwise when presenting the benefits of wet agriculture. While rice may not be able to match corn for raw yield, the carbon-capture economic benefit from rice, a crop that doesn't

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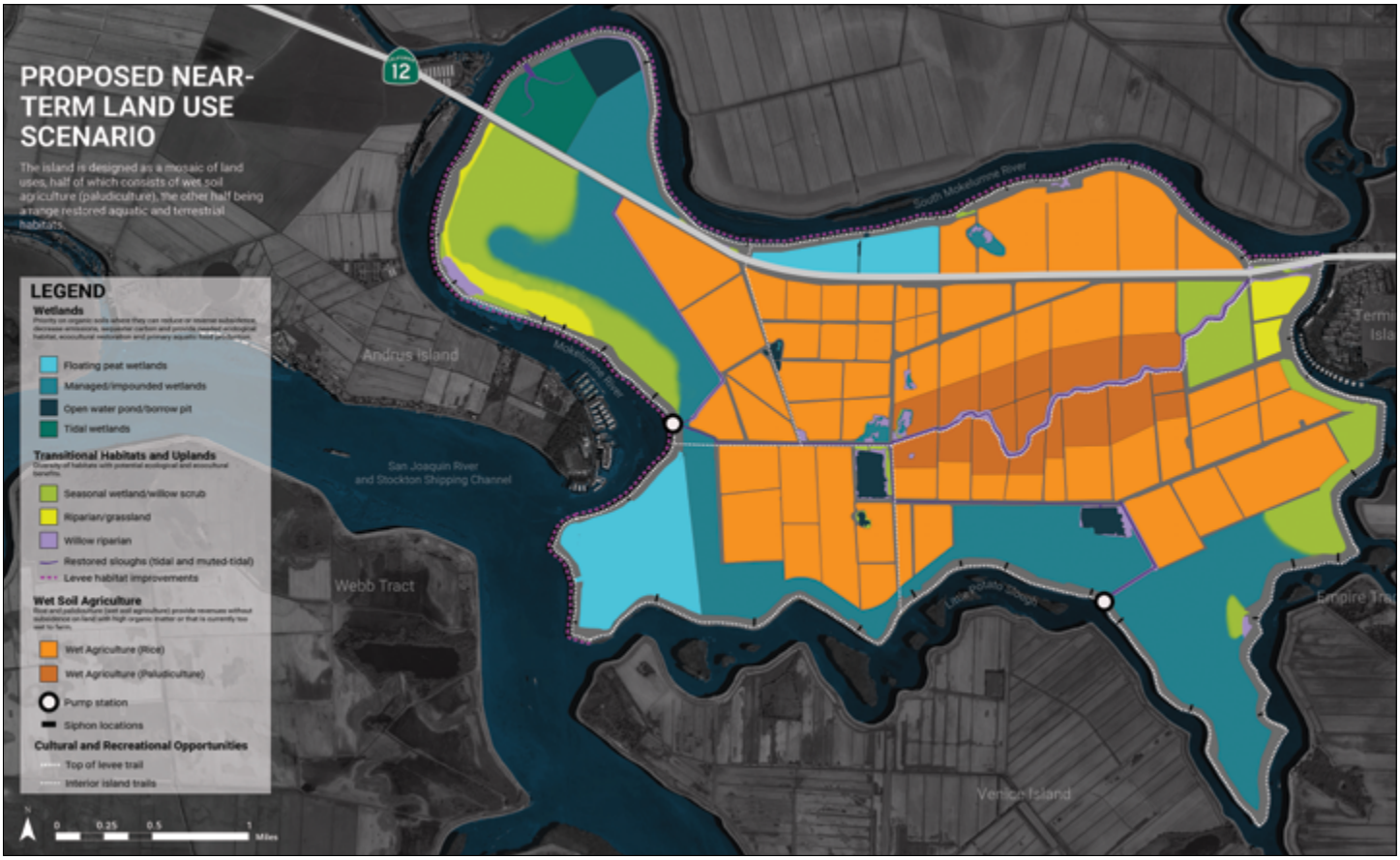

Proposed near-term land use scenario for Bouldin Island.

LEFT: Experimental floating wetland cylinders offer promise for fish habitat on the island. RIGHT: Levee boils can cause massive structural damage if not caught quickly. Images courtesy of MWD.

contribute to subsidence and greenhouse gas emissions, offsets the loss from reduced total production.

A novel type of wetland farming, paludiculture, could also gain a foothold in the Delta through Bouldin Island. Through farming on wet or rewetted peat soils, paludiculture would minimize CO_2 production while also producing harvestable biomass. A pilot project on Bouldin could provide a blueprint for larger-scale peatland carbon farming, according to the project website.

Boiling Over

Ryan stops his car on the levee along the western side of Bouldin Island and shows me a half-circle of sandbags piled three-high with the open end facing the levee slope. A PVC pipe extends from within the circle then down and away from the levee. "We call this a boil," he says. A boil is when water from outside the island finds its way through a weakness in the levee structure and begins bubbling through on the other side. If the water is murky, it indicates that the surfacing water is bringing levee material with it. If it's caught quickly, the material can be collected within the sandbag barrier while the water is drained through the pipe. If it's not, the boil can turn into a major levee breach.

At Bouldin and many other Delta islands, land managers are racing to develop a more sustainable design before sea-level rise and acts of nature turn them into artificial lakes. "Time is critical," says Ryan.

To move the project along, the team has relied on both transparency and participation from Delta communities and stewardship groups. "[The Metropolitan Water District] wants a long-term strategy for these islands," says Milligan. "They will make the final decision, but they're interested in being a good neighbor and retaining some of those aspects of the Delta that are valued by local communities."

Public support for the project is broad, and majority opinion aligns well with the technical advisory committee's stated priorities. Even so, mistrust of the outsider water district remains. Public comments like, "I don't trust [Metropolitan Water District] at all," and "how can the Metro. Water Dust. [sic] of L.A buy and own our Islands?" checker the public survey results.

"By bringing these people together you are hopefully initiating a social learning process," says Milligan. "It's very different from how we did things in the past: privilege one objective over the others. Generally, I think the benefit is in trying to integrate."

A Metropolitan Water District decision-maker's meeting is scheduled for July, where final word on the future of Bouldin Island will be handed down. It's difficult to say what goes on behind closed doors, but, if the past is any guide, the collaboration and consideration that have defined the project so far should mean there won't be any surprises.

Then it's time to hit the ground running on remaking Bouldin Island before the levee boils over.

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A public meeting about the future of Bouldin Island. Courtesy Brett Milligan

LOOKOUT SLOUGH

Tidal Wetlands Restoration Will Be the Delta's Largest

JANET BYRON, REPORTER

When the restoration of Lookout Slough is complete, Lookout Slough will be no more. Created to provide water for a century-old duck-hunting club, the human-made canal will be filled in as part of a $119 million, 3,400-acre tidal wetlands restoration, the largest ever in the Sacramento-San Joaquin Delta.

"Drought and climate change have elevated the importance of these types of multi-benefit projects," said Karla Nemeth, director of the California Department of Water Resources, when the project broke ground last June. "This project will reduce flood risk for communities in the Central Valley and create much-needed habitat for Delta smelt and other endangered and threatened fish species."

By their expected completion in late 2024, the new tidal wetlands will replace former irrigated pasture and duck-hunting clubs in eastern Solano County at the lower end of the Yolo Bypass. In addition to creating shallow-water aquatic habitat, the transformed area will provide 40,000 acre-feet of water storage to help prevent flooding and protect surrounding communities.

"The current science is that between 60,000 and 80,000 acres of habitat need to be restored in the Delta," says Charlotte Biggs, project manager for the Department of Water Resources (see also p. 8).

Lookout Slough is adjacent to two completed tidal wetlands restorations, Lower Yolo Ranch and Yolo Flyway Farms, which are about 2,000 acres combined, as well as Liberty Island, which provides open-water and shallow habitat, Biggs says. It is also a critical piece of 16,000 contiguous acres of restored wetlands planned for the Cache Slough region. "Restoration has more of an impact at the landscape scale," Biggs says. "The larger these restored areas are and the more connected they are, the more benefits they will provide."

Constructing a tidal wetland

The Lookout Slough restoration site is bordered by Liberty Island Road to the north; Shag Slough to the east; and Duck, Hass, and Cache sloughs to the west. Ecosystem Investment Partners (EIP), a national private-equity environmental restoration firm, has managed all of the project's planning, design, permitting (by nine state and federal agencies), and now, construction. When the restoration work is complete, EIP will "hand over the keys" to the Department of Water Resources for long-term management.

Tidal flows were restored to Vogel Island in 2022. Photo: DWR

In February, construction of the new marsh was well underway, albeit somewhat slowed by winter rains. Leading a tour of the huge construction site, EIP project manager Stephanie Freed pointed out the 60-acre portion of the property, known as Vogel Island, that was restored to tidal flow by breaching 1920s-era agricultural berms adjacent to Cache and Hass sloughs this past October. "It's functioning just as we designed it to," she said.

Constructed tidal channels and restored Vogel Island wetland at Look Slough. Photo: EIP/Bill Arnerich

The existing levees around the larger Lookout Slough property continue to restrict tidal waters from the remaining 3,100 acres until a 25-foot-high setback levee can be completed at Duck Slough. Then, a network of more than 20 miles of new channels will be constructed within the property, followed by the breaching of Shag Slough in nine places to allow in the natural flow of the tides.

Creating aquatic habitat

The Department of Water Resources will receive credit for about 3,000 acres of restored habitat for the endangered Delta smelt, partially fulfilling the agency's obligation to create 8,000 acres following a 2008 Biological Opinion issued by the U.S. Fish and Wildlife Service. The new aquatic habitat is also consistent with the 2009 Biological Opinion issued by the National Marine

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Left: Endangered giant garter snake on a public access road. Right, Western pond turtle, safely relocated.
Photos: EIP/Bill Arnerich

Fisheries Service regarding operations of California's State Water Project and the federal Central Valley Project.

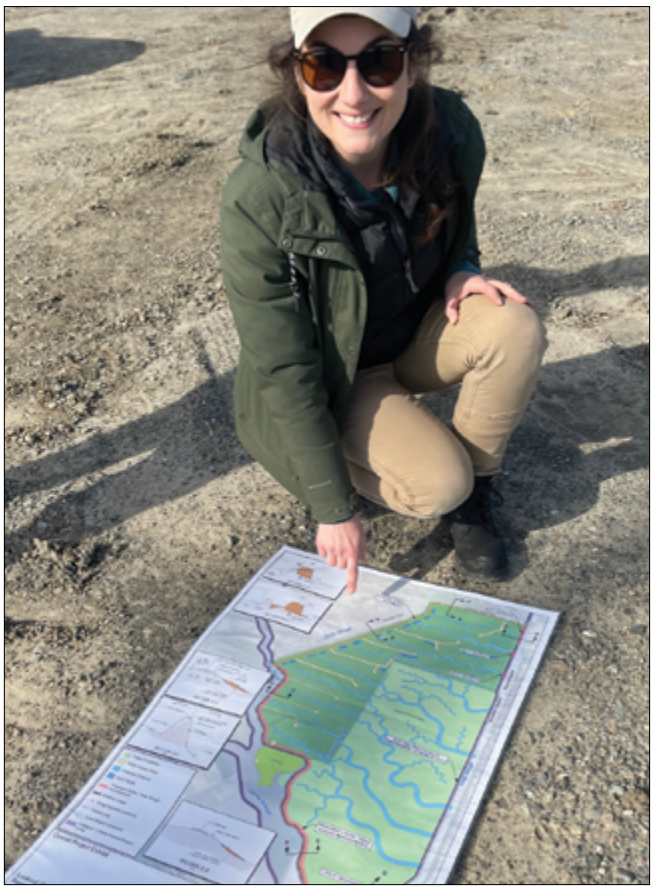
In addition to Delta smelt, the project is expected to support longfin smelt, Chinook salmon, green sturgeon, steelhead, numerous birds, and the threatened giant garter snake, a five-foot-long snake found only in about a dozen isolated marshy areas of the Central Valley. "The EIP project team actually discovered that the giant garter snake was here," says Bill Arnerich, lead biologist for the project. He identified five giant garter snakes and relocated three outside of the work area unharmed during the first year of construction. In addition, throughout construction the project is maintaining a 54-acre relocation area that "has all the habitat elements that the snake needs," Arnerich says.

Return of the Delta smelt?

When complete, 75% of the Lookout Slough wetlands will be intertidal habitat and 17% subtidal habitat; the rest will be upland areas including levees, access roads for PG&E transmission towers, and islands where birds can roost and nest.

While numerous marsh-dependent species will undoubtedly benefit from the new habitat, the jury is still out on whether any amount of new tidal wetlands can bring back the Delta smelt. John Durand, senior research scientist with the UC Davis Center for Watershed Sciences and a board member of the area's Reclamation District 2098, applauds the transformation of "a huge swath of low-value rangelands" into aquatic habitat. However, he is concerned that invasions of aquatic weeds will clog up tidal waterways and obstruct native fishes such as the Delta smelt, which is, he says, functionally extinct. "One restoration project is not going to be able to save the smelt."

State and federal agencies are not giving up on the Delta smelt. "We're very aware of this issue of invasive weeds and how they threaten the functionality of the shallow-water habitat ecosystem," says Louise Conrad, Department of Water Resources lead scientist. The agency has an agreement with the California Department of Fish and Wildlife to monitor and study invasive species and their impact on the aquatic food web, plus a $30 million partnership with the California State Parks Division of Boating and Waterways to treat invasive aquatic vegetation in restored delta wetlands, including with nonherbicidal treatments such as mowing and burning, Conrad says.



EIP's Stephanie Freed with slough restoration map.
Photo: Janet Byron

For the past year, UC Davis fish scientists have released thousands of hatchery-raised Delta smelt near Rio Vista and tracked their movements in an effort to figure out if and how the finger-size fish can be brought back from the brink of extinction. "Lookout Slough is not a silver bullet for restoring Delta smelt," Conrad says. "We're trying to stand in the way of complete extinction and reverse its population trajectory to one that is positive."

Regardless of how the Delta smelt fares, Biggs says that a restored Lookout Slough will provide a multitude of benefits for aquatic ecosystems, people, and the Delta. "This project provides benefits to the whole food web, not only for Delta smelt but also larger fish, birds, and wildlife that benefit from having more food sources in the Delta."

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SUISUN MARSH

Working Landscapes Support Fish

ALETA GEORGE, REPORTER

On a sunny spring day in 2014, two UC Davis PhD candidates in waders pulled a 30-foot seine through Luco Pond (also known as the Potrero Duck Club) in Suisun Marsh. Luco Pond is within the Nurse-Denverton Slough Complex where duck clubs use tidal gates to control water exchange. After 45 minutes of counting diminutive fish, Brian Williamshen and Melissa Riley were excited to tally more than 6,900 sticklebacks, a thorny-backed native fish in the Sacramento-San Joaquin River Delta.

"There was definitely a moment of excitement," Williamshen says. "But when we were at our 50th fish, and the little spines kept poking us in the fingers, our emotions shifted to like, oh man, we still have hundreds more to go!"

Several months later, Williamshen pulled a seine at Blacklock Marsh, another site in the Nurse-Denverton Slough Complex. Blacklock is a former duck club that was restored to an open tidal marsh with two breaches in 2006. One of the goals of the project was to improve habitat for endangered species like Delta smelt, but instead of finding native fish, Williamshen counted 874 Mississippi silversides, an invasive fish that had flowed in unrestricted with the tides.

"Silversides compete with species like Delta smelt," says Peter Moyle, UC Davis professor emeritus who started the Suisun Marsh Fish Study in 1980. "When silverside numbers are high, other fish numbers tend to go down."

Moyle's monthly fish study was taken up by the Aquatic Research Collective at UC Davis' Center for Watershed Studies after he switched to emeritus status, though Moyle continues to serve as an advisor.

The passage of California Proposition 1 resulted in a push to restore wetland habitat, including the conversion of "working" wetlands to open tidal wetlands in the Suisun Marsh. Williamshen's two-year study kicked off a series of studies that have been conducted by the Aquatic Research Collective to determine if the restoration of managed wetlands in the Suisun Marsh were achieving their goals to help native fishes.

"Our findings, over and over again, come back to the same conclusion" says John Durand, senior researcher at the Collective. "We're seeing a degradation in the quality of habitat as a result of wetland-to-wetland restorations."

Though much of San Francisco Bay's wetlands have been filled and built upon, most of the Suisun Marsh has been conserved by more than 150 private duck clubs for hunting.

Seining Luco pond. Photo: Brian Williamshen

Managed wetlands are ecologically functional habitats, and not just for waterfowl, Durand says. It turns out they are good for aquatic food production and fish, too.

Durand didn't start out thinking this way. Neither did Moyle, who says that fish people tended to ignore duck club people until about ten years ago when UC Davis students sampled water at duck clubs in Luco Pond. Their findings demonstrated that duck club ponds could be a significant source of food for fish.

Duck clubs close their tidal gates in summer when they grow annual plants such as fat hen and sea purslane to attract waterfowl. In autumn the clubs open their gates to exchange water with adjacent sloughs. Plant materials decay and seeds float to the surface, resulting in "giant blooms of productivity that are phenomenal," says Durand.

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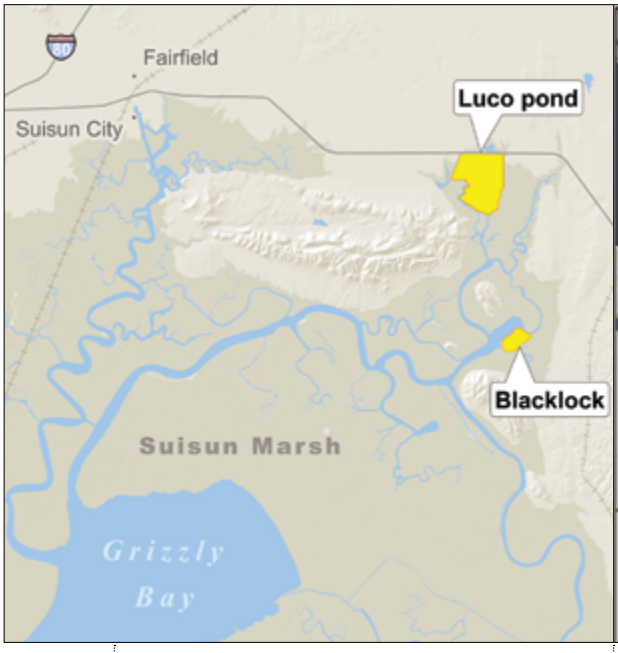
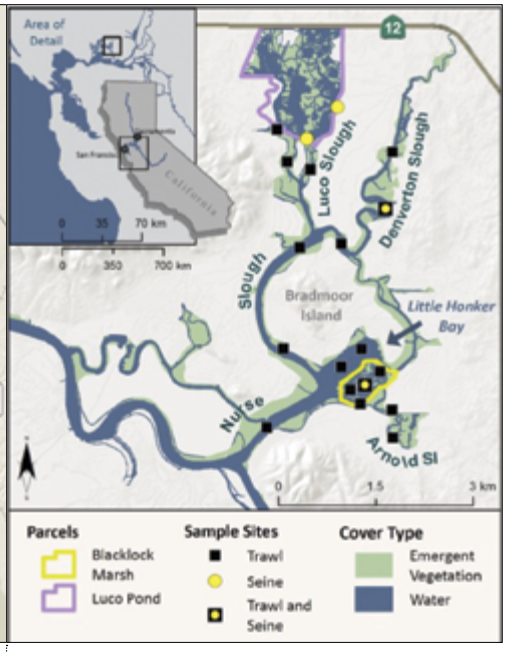


Map: Amber Manfree



Map: Brian Williamshen

Blooms like these may help mitigate a decline in plankton that has occurred in the San Francisco Estuary since the late 1980s, primarily due to the ravenous appetite of invasive clams. The lack of food at the base of the web has contributed to a decline in fish, including Delta smelt and Chinook salmon.

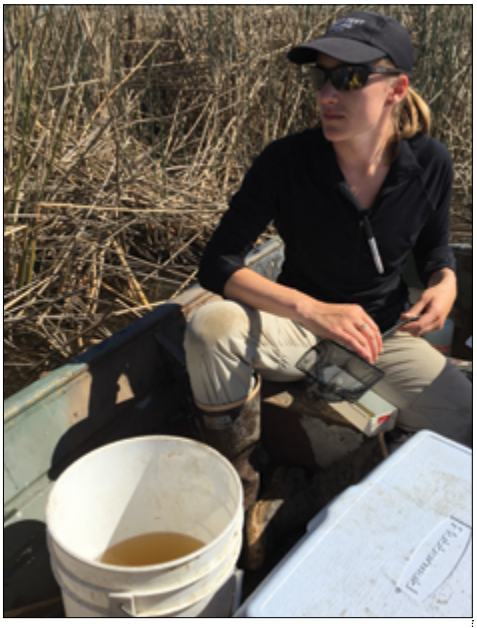
"We were dismayed to see that there was a negative effect at Blacklock compared to adjacent habitats," says Durand. Williamshen's study was the first to show that the restoration of a managed wetland can have counter-intuitive results, while also showing that an adjacent managed wetland was extraordinarily productive.

"What she found blew her away," says Durand. "The fish did not do well in the natural slough and the fastest growth occurred near the outlet of the managed pond."

Kwan concluded in a paper published in the April 2020 issue of ***Estuaries and Coasts***, "This is the first study in the San Francisco Estuary to demonstrate that a productive tidally muted managed pond can benefit rearing salmon. Contrary to our expectation, salmon grew considerably faster in the managed pond outlet relative to the other locations, with observed growth rates that were comparable to other productive habitats."

Navigating Denverton Slough. Photo: Katie Smith

Williamshen was one of the undergrad students who had sampled water in Luco Pond. After he graduated, the Aquatic Research Collective helped him design a study. From October 2013 to July 2015, Williamshen and his team (including Melissa Riley, Teejay O'Rear, Durand, and Moyle) motored through sloughs and bays to sample water quality, zooplankton, and macroinvertebrates. They captured, identified, and measured fish at Blacklock Marsh, Luco Pond, Little Honker Bay, and Arnold, Luco, and Denverton sloughs.



Researcher Nicole Kwan. Photo: John Durand

Williamshen concluded in his paper published in the March 2021 issue of ***Restoration Ecology***, "Our research suggests that restoring tidal action to managed wetlands alone may worsen rather than improve conditions for at-risk and native fishes."

The Aquatic Research Collective next evaluated managed ponds as potential Chinook salmon nurseries. In spring 2017, Master of Science candidate Nicole Aha (now Kwan) grew juvenile salmon in cages at four sites: a natural tidal slough, a leveed tidal slough, and at the inlet and outlet of a managed wetland. "We expected salmon to grow fastest in the natural tidal slough because it best represents historic salmon habitat in the marsh," she says.

To prepare for her experiment, Kwan and her team (Nann Fangue, Andrew Rypel, Moyle, and Durand) evenly divided 252 fall-run juvenile Chinook salmon grown in a UC Davis lab into 18 cylindrical cages. Then they reared the .01-ounce salmon in cages placed in First Mallard Slough, a natural tidal slough at Rush Ranch; Sheldrake Slough, a leveed tidal slough between two managed wetlands; and an inlet and outlet of Wings Landing Duck Club. From March 1 to April 21, 2017, Kwan weighed and measured the fish every two weeks. On each visit, she euthanized three fish per cage and took them back to the lab to examine what was in their stomachs.

Salmon grown and studied in productive habitats include the "floodplain fatties" reared in flooded rice fields in the Yolo Bypass. Around the same time that the Aquatic Research Collective was conducting its studies in the Suisun Marsh, another group of scientists at UC Davis's Center for Watershed Sciences was monitoring the growth rate of juvenile salmon in flooded rice fields. They watched the salmon grow fast and fat because the flooded rice fields created phytoplankton or mobilized detritus. Either of these phenomena can fuel a zooplankton bloom that feeds baby fish. "We find the same effect here," Durand says. "It's the managed working landscapes that are extremely beneficial."

In another study, the Aquatic Research Collective compared plankton production in managed wetlands to adjacent tidal waterways. In that 2018-2021 study, UC Davis PhD candidates Alice Tung and Kyle Phillips confirmed that ponds produce more food for fish than do tidal waters. They completed

a Suisun Pond Productivity report in 2021, but their papers on the study have yet to be published.

The Collective has funding to further their studies. One will expand on Nicole Kwan's work. In another they will look at how managed wetlands work, why they're productive, and what can be done to manage them more

water at the same time native fishes are in their larval stages and growing on zooplankton.

The Nurse-Denverton Slough Complex is unique among San Francisco Estuary wetlands for another reason. Its upper reaches are connected to uplands that aren't urbanized or built upon, giving the marsh

Instead of restoring managed wetlands into open tidal wetlands, Durand and his Collective envision a restoration model that manages connectivity. "Having a coupled system, like a working landscape with a naturalistic landscape, could be highly productive [for fish]. Geomorphology, active management and water hydrology would all

Luco Pond. Photo: Brian Williamshen

effectively for fish and fowl. Decades of data from the Suisun Marsh Fish Study reveal that Suisun Marsh has the most diverse community of fishes in the upper San Francisco Estuary, and Durand believes its managed wetlands, including those in the Nurse-Denverton Slough Complex, are a factor in that.

The slough complex stretches from Montezuma Slough to California State Route 12 west of the Western Railway Museum. Nurse Slough flows along the west side of Broadmoor Island and splits into the sinewy sloughs of Luco and Denverton, flanked by tules, cattails, and common reeds. Denverton Slough slips under CA-12 into ephemeral drainage, while Luco Slough joins Luco Pond where duck clubs exchange

room to migrate when sea levels rise. "Climate change is going to alter this landscape without active management. At sites where we simply breach the habitat, like at Blacklock, sea-level rise will flood them in the next 50 years or so and they're going to become subtidal habitat and lose a lot of benefit," says Durand.

The marsh could provide some protection if it were altered to maintain the landscape. "One way to do that is by working with private duck club owners," says Durand. "I suspect that the private and state owners of managed wetlands will resist [rising waters] because they have more incentive to do so. We should be forming partnerships with landowners in the region to try to help them maintain and buffer their levees."

Blacklock with birds. Photo: Brian Williamshen

A portion of Luco Pond is being considered for open tidal restoration. The Aquatic Research Collective believes that would be a mistake. "We should understand it before we decide to breach it and put in the kind of restoration that my group keeps finding is not very productive," says Durand. "We think we'll see a degradation of the whole system."

come together in this," Durand says. "It's complicated, but it could be more productive than the sort of restorations we're doing now. The breach and hope strategy is just not very useful."

Williamshen says that doing his study shifted the perspective he had learned in school. "It's important for people to know that our science is showing that it's not what we thought. Instead of these duck clubs being harmful, they're productive and benefit native fish. You think you're doing good for the ecosystem by restoring it, but we're finding that's not actually the case."

A decade of studies has left Durand asking, "Why create 'new' wetland habitats out of wetland habitats that are already functional?" This question, and the pursuit of data that can help answer it, continues.

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ENVIRONMENT

Agreement Highlights Habitat Questions

CARIAD HAYES THRONSON, REPORTER

Restoring marsh and wetland habitat can have significant benefits for dozens of species throughout the Bay and Delta — that's beyond dispute. But when it comes to saving the Estuary's most imperiled fish, how much habitat improvements can help in the absence of dramatically increased freshwater flows is a question that has dogged and divided scientists and policy makers for years. As the State Water Resources Control Board considers the latest proposal from the State and water agencies for a flows agreement that would restore thousands of riparian and wetland acres — while dedicating less water to the environment than proposed under an alternative regulatory framework — critics argue that science doesn't support its underlying assumptions. The debate highlights how much there still is to learn about what restoration efforts can and cannot do for the Delta's ravaged ecosystem.

Sacramento River flows after January 2023 storms. Photo: Kenneth James, DWR

In January the State Board released the Draft Scientific Basis Report analyzing a voluntary agreement (VA) on freshwater flows into and through the Delta from the Sacramento and Mokelumne Rivers that was proposed by a group of water districts and state and federal resource agencies last spring. The Board is considering adopting the agreement as a pathway to implementing its long-delayed update to the Bay-Delta Plan Water Quality Control Plan. The new report supplements a 2017 Scientific Basis Report supporting Board staff recommendations for minimum unimpaired flows to protect native fish and wildlife.

The proposed agreement outlines an eight-year program that proponents say would add up to 825,000 acre-feet of freshwater flows for the environment annually and restore more than 27,000 acres of spawning, rearing, and floodplain habitat to reverse the decline of salmon and other native fish populations. Twenty-thousand acres of that habitat would consist of restored and reconnected floodplain in the Sacramento River. (See related story p. 11.)

The new science basis report finds that the proposed flows would benefit longfin smelt, Sacramento splittail, starry flounder, and California bay shrimp, among other species. "The results show that we would see an improvement in abundance indices for some Delta species related to flow measures," says Department of Water Resources lead scientist Louise Conrad. The report does not, however, measure the effect of the proposed flows on salmon or steelhead abundance.

The proposed flow regimes aren't nearly large enough to protect endangered species and fisheries, critics say.

For starters, the amount of water the VA would actually provide depends on the baseline used. Critics say the 825,000 acre-feet number is misleading, since it uses a baseline that includes the flows required under discredited 2019 Biological Opinions for endangered fish that dramatically increased permissible water exports. (California sued the federal government to invalidate those BiOps on the grounds that they did not protect fish, and in 2021 the Bureau of Reclamation launched a process that will lead to new BiOps, probably by 2024.) The new science basis report notes that the VA baseline "does not fully reflect the Delta outflow conditions of the environmental baseline" used in the 2017 science basis report, and adjusts its analysis accordingly. Using this "apples to apples" approach, a chart included in the report indicates that the VA would provide much less than 825,000 af in all year types — although the report does not spell that out, leaving the reader to compare flows using different baselines and do the math.

And whatever the baseline, critics also like to point to the State Board's own 2018 framework for the Sacramento River, which called for 45% to 65% of unimpaired flows from the river and its tributaries into and through the Delta — much more than 825,000 acre-feet.

Critics are not entirely convinced, either, that more habitat necessarily means more fish, an assumption upon which the voluntary agreement rests.

"They're trading habitat for flow, but this doesn't have a basis in science," says San Francisco Baykeeper science director Jon Rosenfield.

Jennifer Pierre, general manager for the State Water Contractors, who helped negotiate the voluntary agreement, rejects the premise that it trades water for habitat. "We are certainly combining habitat and water, but it's a huge amount of water," she says.

continued on page 42

SOUTH BAY SALT PONDS

Taking the Measure of Success

JOHN HART, REPORTER

It is two decades now since some 23 square miles of South Bay salt evaporation ponds became public property. Eighty-eight old impoundments were to be remade into habitat for birds and other creatures — and into a superior flood-control buffer for communities beside the rising Bay.

Progress since then has been slow, and fast. Slow, because relatively small swathes of territory have been visibly, obviously changed. Slow, because a whole set of basic questions had to be answered before the work could pick up speed. And fast, because those questions have now been answered, by and large, and the news is pretty good. As sea-level rise makes the project ever more urgent, the way seems open to a rapid transformation in the years to come.

The playing field is 15,100 acres in three blocks. On the eastern shore, just south of the Hayward-San Mateo Bridge, is Eden Landing, with about 5,500 acres. On the western shore, at the San Mateo end of the Dumbarton Bridge, lies the Ravenswood cluster, just under 1,700 acres. The large remainder, almost 8,000 acres, wraps around the southernmost tip of San Francisco Bay: the Alviso ponds.

Alviso and Ravenswood are parts of the Don Edwards San Francisco Bay National Wildlife Refuge; Eden Landing is a State Ecological Reserve. The U.S. Fish and Wildlife Service and the California Department of Fish and Wildlife, however, have joined in what looks like a seamless effort: the South Bay Salt Pond Restoration Project, currently headed by Dave Halsing on behalf of the California Coastal Conservancy, the project's primary administrator and sponsor.

Before restoration could begin, there was a major housekeeping task: the purging of a system overcharged with salt, and its replumbing for wider purposes. The Cargill pond sequences, known as "plants," were like conveyor belts, taking Bay water through a series of ever-saltier impoundments until all that remained was sodium chloride and the residual chemical mix called bittern. As a condition of sale, Cargill essentially ran the belts in reverse for a while. After taking title, the new managers replaced the industrial valving with an elaborate system of gates, allowing better control of salinity and tidal exchange.

Eden Landing. Photo: John Hart

Meanwhile, next steps were pondered.

Before the salt ponds (and urban landfill and diking projects) were built, the entire South Bay had been encased in marsh. Couldn't that scene be largely recreated? To start such a process — to reconnect diked areas to the tide — would be easy indeed. John Bourgeois, the project's previous manager, liked to say: "Give me an air boat and a box of dynamite, and I'll restore the marshes." But such a revolution could not be launched lightly, or without regard for the surrounding cities. As Bourgeois hastened to add: "I'd destroy the infrastructure, too."

Also, for all the ecological services they provide, marshes aren't good for everyone. Open, sheltered waters and even desiccated flats are vital to various species of birds. Ponds of moderate salinity swarm with brine shrimp, a major avian food item. As similar habitats elsewhere dwindled, many Cargill ponds became wildlife havens by accident, harboring roughly the species you'd find at a saline desert lake like Mono: gulls, terns, grebes, plovers, phalaropes. (See also p. 9).

Ravenswood. Photo: John Hart

So how much acreage should now go to wild pickleweed and cordgrass, how much to ponds and other managed habitats? The first generation of planners joked about being "Marshists" or "Pondinistas." Of course everyone was a bit of both; the trick was to define a balance.

The comprehensive plan released in 2008 left the matter somewhat open. At least half of the restored acreage would be marsh, but that proportion could mount as high as 90% — provided the needs of open water birds were also being met. Pilot projects were launched to answer questions about each of these management forms.

QUESTION: Is there enough mud to make all these marshes?

TESTING GROUND: Island Ponds, Ducks Head, Old Alameda Creek.

When Bay muds dry out, they oxidize, so that the ground sinks. Saltmaking had kept most areas wetted, most of the time, yet some tracts had subsided a good deal. This was especially the case near Alviso, where excessive groundwater extraction had caused the very foundations of the shore to sink. How quickly would the mud suspended in South Bay waters settle out in the reconnected ponds, building soil and supporting renascent marsh?

The prototype was a group of then-dry tracts near Fremont known as the Island Ponds (A for Alviso 19, A20, A21). Wedged between Coyote Creek and lands retained by Cargill, they were not as subsided as some others; also, they didn't butt up against developed areas — the rare case where the question of flood control didn't arise.

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Ecotone levee at Alviso ponds. Photo: John Hart

In 2006 the dikes along Coyote Slough were breached in five places. The results at first were mixed. The westernmost pond, A21, responded even faster than expected; within ten years, it had generous marsh vegetation and supported salt marsh harvest mice and Ridgway's rails. But A20, farther in from the Bay, was slower to respond. A19, the easternmost, lagged even more. The lesson derived was not that sediment was lacking but rather that the dike breakers should have made more and larger openings to let more silt-laden water in. In 2021, the team added breaks along the north side of the project, into the encouragingly named Mud Slough. It is too soon to judge the response.

No such problems beset additional tracts opened up four years later: Pond A6 north of Alviso, named the Ducks Head for its distinctive outline, and a group in the Eden Landing area, along the channel known as Old Alameda Creek. Sedimentation and revegetation have been rapid in these places.

These results matched hopes based on geography. In this southernmost chamber of San Francisco Bay, shallow and windblown, bottom muds are constantly stirred up, often making waters more brown than blue. Additional sediment swirls in from the central Bay. The particles will settle where they can.

Yet the supply is not unlimited, and biologists worry that the Bay system as a whole is entering a phase of sediment deficit. Stuart Siegel, author of early salt pond restoration studies, wishes for detailed bathymetric work to refine understanding of where sediments move. Noting the habitat value of mudflats, he wonders: "Are we strip-mining the flats for the sake of new marshes? It's possible."

A USGS assessment in 2018 concluded that "there is sufficient sediment to restore marshes and maintain mudflat habitat, but concern in light of long-term trends."

QUESTION: Is there enough dirt to make all those levees?

TESTING GROUND: Many sites.

As part of the South Bay Salt Pond Restoration Project, or at least in concert with it, tens of miles of levees are being strengthened or built anew. Many of these are to be "horizontal" or ecotone levees, sloping gently outward on one side to support several habitat zones even as the water rises. At Eden Landing, an ecotone levee will divide western ponds headed for marsh conditions from eastern ones that are to be enhanced for birds. From the Alviso Marina County Park, one can see machines at work on a new levee stairstepping northward from this spot to Milpitas. This is the San Francisco Bay Shoreline Project Phase One, a formally separate undertaking of the U.S. Army Corps of Engineers and the Santa Clara Valley Water Agency (Valley Water), along with the Coastal Conservancy.

Some of the ecotone levees merge into the artificial hills that here and there rise from soggy flatlands: old landfills. In a landscape short of vertical relief, these monuments to waste now offer room for plants and animals to shift their ranges upward. Halsing remarks wryly: "Landfills are one of the best things people have done for sea-level rise." The ecotone buffers incidentally keep marsh water from leaching into the buried, albeit lined, garbage deposits.

But the dirt! Vast quantities are needed. Project managers are constantly on the lookout for sources of clean fill. Urban construction projects are always disgorging earth and rock, and what could be more practical than to truck the stuff to nearby wetland sites? A recent development in downtown Sunnyvale provided one such windfall: more than 250,000 cubic yards of clean fill for use in different parts of the Restoration Project. However, a surprisingly small fraction of candidate material tests out as clean enough to use, and timing is an intricate dance. The receiving site must be ready to take the fill immediately after its excavation; any stockpiling increases costs tremendously.

Muted marsh at Alviso. Photo: John Hart

QUESTION: Will reconnecting ponds stir up mercury?

THE TESTING GROUND: The A8 ponds near Alviso.

The very southern limit of San Francisco Bay today is Pond A8S, at the foot of Great America Parkway, within walking distance of Levi's Stadium. This and three ponds adjoining to the north were slated for marshland, but full tidal connection was deferred due to a lurking problem: mercury.

There is a lot of this toxic metal in South Bay muds, derived mostly from a local source, the New Almaden Mine at the headwaters of the Guadalupe River. Contaminated tailings washed down into the old marshes. Then the salt ponds took over. Could the clock now be turned back safely? Or would marsh restoration stir the poison up and introduce it, in the biologically active form of methyl mercury, into the food chain?

When this set of ponds was prepared for tidal reconnection, a kind of emergency brake was built in. A narrow and fortified tidal gate was emplaced, allowing the managers to cut off the link at any time; the area could default to permanent managed pond.

When the tides were admitted in 2011, mercury levels did indeed surge. This was an expected effect of construction disturbance. The good news was that the toxin quickly subsided to background levels. This outcome boded well for more than one site only. If the mercury problem was evanescent here, it would probably pose little threat anywhere else.

QUESTION: Will invasive plants compromise new marshes?

TESTING GROUND: Wherever dikes were broken.

In 1973, as mitigation for dredging, the Army Corps of Engineers set out some cordgrass on the banks of the Alameda Creek Flood Control Channel just south of Eden Landing. Unfortunately, the chosen species was not the native California cordgrass but instead one called smooth cordgrass, a mainstay of East Coast marshes. A blameless citizen of its native ecosystem, smooth cordgrass proved an aggressive invader here. It not only outcompeted the local grass but also occupied habitats the local strain left bare, choking sloughs and blanketing mudflats. At the time the Salt Pond Restoration Project was conceived, the invasion was near its peak. Would newly created marshes become smooth cordgrass monocultures, uniform plains of diminished habitat value?

Eden Landing drainage with tides. Photo: John Hart

California responded with the San Francisco Estuary Invasive Spartina Project, a multi-agency campaign led by the Coastal Conservancy. Since its launch in 2000, the project has succeeded in reducing the problem from a crisis to a chronic maintenance issue. Smooth cordgrass is no longer an impediment to salt marsh restoration. (See also p.38.)

Harmful exotic species don't stop arriving. While combatting the old invader at the Island Ponds, biologists spotted a new one: the fast-spreading eastern turfgrass Paspalum vaginatum. A timely, targeted application of herbicide may have headed off a much larger problem.

QUESTION: How finely should we tune salinity in ponds?

TESTING GROUND: Ponds E12 and E13 at Eden Landing.

A trail at Eden Landing Ecological Reserve shows off this laboratory. Along with the moody ruins of pre-Cargill salt works, visitors often notice strange tinges in the water. Low levees subdivide two large ponds into smaller units, each managed for a different salinity and hence developing a different color. It's a miniature of the Cargill pond patchwork so often noticed from the air. The intent here was to see if different species and guilds of birds would favor different levels of saltiness. The results were rather surprising: though the mini-ponds were all valuable habitat, the expected sorting by species was rather weak. Micro-management of salinity may yield less reward than thought.

QUESTION: Do constructed habitat islands work and what is the best design?

TESTING GROUND: Pond SF2 at Ravenswood, Pond A16 near Alviso.

To protect its levees from wind-driven waves, Cargill created "sacrificial islands" in its ponds, piles of mud that harmlessly absorbed the pummeling. Biologists eventually noticed that these high spots were favorite resting and nesting spots for many species of birds. Surely islands built deliberately for habitat would be better still!

To determine the best shapes, sizes, and spacings, managers constructed two archipelagos. A swarm of 30 islands, some roundish and some skinny, dot Ravenswood Pond SF2, just south of the Dumbarton Bridge. In Pond A16 at Alviso, the islands are fewer, larger, and more widely spaced. Conclusion after several years: shape matters some (the linear islands were preferred to rounder ones), but size and separation matter more (bigger and farther apart is better). David Halsing says of the Ravenswood site: "I don't think we'll do anything that elaborate ever again."

SF2 also taught a lesson about island surfaces. Piled-up bay mud cracked as it dried, making little traps in which plover chicks got stuck and died. The ground had to be reworked with dirt and sand. Later on, different surface treatments were devised to discourage the growth of bushes that terns and other nesters avoid.

QUESTION: Overall, can the numbers of pond-loving birds be kept high?

TESTING GROUND: Everywhere.

From the beginning, biologists have tracked, with some anxiety, the occurrence of all those birds that don't directly benefit from marshes: ducks and geese, stilts and avocets, terns and gulls. How these respond will dictate the final balance between tidal wetlands and managed ponds. (See also

continued on next page

Photo: John Hart (SF2-signage)

p. 29.) So far the news is inconsistent, yet largely good. Migrating waterbird numbers have doubled since the work began. On the downside, snowy plovers have barely held their own, due not so much to habitat loss as to predation: crows and gulls, especially, carry off many chicks. Terns initially proved skeptical of the carefully planned islands, but were successfully lured back by decoys and recorded calls.

Western snowy plover.
Photo: William Chan, USGS

Moving On to the Next Phase

Phase 1 of the project officially wrapped up in 2015. More than 1,500 acres of marsh had been set on the road to restoration; approximately 700 acres of ponds had been improved; and some 1,400 acres, the A8 ponds, were in a kind of limbo as "reversible tidal." At this point, the USGS summed up a decade of experience and assessed the prospects, revisiting questions first posed in 2008. In the majority of categories, the outlook was described as "uncertain, trending positive." Given that uncertainty is a permanent condition, the road ahead seems pretty clear.

On the agenda now are the breaching of Pond R4 at Ravenswood, due this year; a square mile returned to the tides at Mountain View; and the conclusion of major work at Eden Landing. Valley Water is taking the lead in revitalizing the A8 pond complex at Alviso, which now seems destined to be fully tidal. Just east of that, the Army Corps and Valley Water are in charge of 2,900 more acres of ponds north of the new Shoreline Levee. When the barrier is complete, nearly all of this swathe will be restored to tidal action.

When these actions are completed, over 8,000 acres will be headed toward a marshy future, and something under 2,000 acres will have been reserved for managed ponds, muted marsh with limited tidal exchange, or dry plover habitat. Almost two-thirds of the acreage acquired in 2003 will be spoken for. The 50% minimum target for marsh will already have been surpassed.

The outlook has changed in some ways since 2008. Sea-level rise, though acknowledged back then, has become a much more pressing concern. The challenges of maintaining old levee networks grow even as budgets get tighter. The almost pond-by-pond, species-by-species allocations of 2008 now seem a little beside the point. "Back then," says Halsing, "they thought they had more options and more time."

At Eden Landing and elsewhere, the shape of the future seems to be emerging: an outer belt of marshes; an ecotone levee amidships; and an inner belt of managed ponds. Besides meeting the needs of birds and other creatures, this ecological layer system seems to offer the best protection for one colonial species, attracted to water yet somewhat afraid of it, that clusters very thickly on these shores: human beings.

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Ravenswood. Photo: John Hart

RECONNECTIONS

Transition Zones

The sidewalk superintendents of restoration tend to gaze outwards, towards the Bay. People who are actually doing the work spend a lot of time looking in the other direction, toward the encircling cities and hills. Vital connections run that way. Creeks and flood channels come down. Trucks bring in clean dirt excavated from urban construction sites. Here and there an open, unbuilt parcel promises room for marshes to migrate inland as sea level rises. And always and everywhere there are the neighbors: residents concerned about flooding, noise, and dust; tech giants who might be expected to show more interest than they do in the problems lapping at their doorsteps; cities, counties, and other local agencies with their own agendas, sometimes very supportive, sometimes less so; and a stack of regional (and broader) environmental agencies whose standards and procedures come to bear.

The most obvious bonds between bayshore and hinterland are the streams. The South Bay's largest are Alameda Creek, Coyote Creek, the Guadalupe River, Stevens Creek, and San Francisquito Creek. The 20th century regarded these as nuisances, to be confined by levees and hurried out to deep water. Now reconnection is the order of the day. Excess flows can pool in managed ponds; the channel-clogging muds that used to be dredged and trucked away can instead help build marshland soil.

At Alviso, for instance, Pond A8 and its neighbors have been relinked to the Guadalupe River. Two smaller creeks, Calabazas and San Tomas Aquino, are to be tied in here as well. At Ravenswood, a new tide gate links a local flood-control channel to a group of managed ponds, serving to reduce flood frequency in vulnerable neighborhoods. In the era of climate change, such exceptional synergies seem poised to become the norm.

"The projects are getting more and more complicated," notes California Coastal Conservancy project manager Evyan Borgnis Sloane. "More than ever, we need strong partnerships."

NOVATO BAYLANDS

More Mud, Please

NATE SELTENRICH, REPORTER

Imagine a complex of tidal wetlands skirting San Pablo Bay unbroken from China Camp to Mare Island, providing vital wildlife habitat and protecting inland communities from storm surge and sea-level rise. With stretches of this shoreline formerly diked and drained (or in Hamilton Wetlands' case, converted to a military airfield), reconnecting it may have once seemed unlikely. Yet today just two gaps remain, one of which is included in a restoration project that's already underway: Bel Marin Keys. And it's a doozy.

The problem is one of scope — and more specifically of mud. The project site, currently partitioned into fields for agricultural use by a grid of berms and drainage ditches, is so large (1,900 acres), and the land so subsided that breaching its Bay-fronting concrete-and-riprap levee would flood much of the property, berms included, with multiple feet of saltwater.

Hence the need for mud: initial designs called for about 14 million cubic yards of it, to raise the elevation sufficiently to allow for the formation of new tidal marsh and transition zone habitat. That's a huge amount of sediment, the equivalent of roughly a million large dump truck loads — or 14 years' worth of dredged material from the Port of Oakland, which in the late 2000s provided 3.5 million cubic yards to the Hamilton Wetlands Restoration Project immediately south of Bel Marin Keys.

Without more mud, the project can't be completed. Numerous potential sources exist, but none have yet to be secured. And given a limited (and declining) supply of sediment in the Bay system, with other restoration sites like Montezuma Wetlands in Suisun and Cullinan Ranch on the north side of Highway 37 also in need, it's a zero-sum game with no easy answers.

"It really becomes this challenge of, 'Where does the sediment come from and how do we get it there?'" says Julie Beagle, an environmental planning section chief with the US Army Corps of Engineers and expert on the use of dredged sediment for marsh restoration.

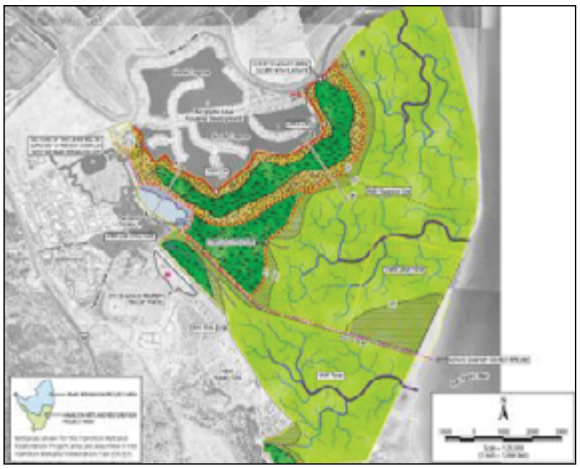
The reality is that it's looking increasingly likely the project must make do with less than the full 14 million cubic yards, says Jessica Davenport with the California State Coastal Conservancy. "The Corps and the Conservancy will be exploring ways to construct the project with a smaller volume of dredged material," she says. "Filling the site to capacity…is looking impractical. We will be considering how to make the best use of a smaller volume of imported sediment, with the exact amount still to be determined."

Not only that, but the source — and delivery method — of the mud still must be settled. Project planners are considering a host of approaches for Bel Marin Keys, some informed by past restoration projects on San Pablo Bay, Davenport says. These include running a pipe across the site to deliver sediment from dredge projects, as was done at Hamilton; building habitat islands from available material, then opening the site and letting it naturally accrete at a slower pace, as was done at Sears Point (which sits next door to the other remaining gap in San Pablo Bay marsh, Tubbs Island); and dividing the site into cells for a phased or multi-method approach, as at Cullinan Ranch.

Other ideas being explored include drawing sediment from and subsequently refilling an "aquatic transfer facility" on the Bay floor, and connecting the site to Novato Creek for sediment delivery, Beagle notes.

Add another question to the list: How long will all this take? "If it takes 20 years to do a project, and we know 2030 is this magic time where marshes need to be in place in order to keep pace with sea-level rise, which is what the Baylands Goals told us …." Well, that's not ideal. "We want to get these projects done," she says. The "landscape-scale" size of Bel Marin Keys, and its connectivity to a restored Hamilton next door, make its impact, and urgency, all the greater.

Techniques used to add sediment to the Montezuma Wetlands included hosing it from a sediment laden barge. Photo: Darren Graffuis



Preliminary, rough schematic of a restored Bel Marin Keys (with the already-completed Hamilton Wetlands to the south); exact details and design elements have yet to be finalized. Courtesy State Coastal Conservancy.

Some critical work has already been completed. A new outboard levee built in 2021, about a mile landward of the existing levee fronting San Pablo Bay, snakes its way from north to south just in front of the Bel Marin Keys housing development. Behind it, new seasonal wetlands and alkali meadows have been constructed. But between it and the open Bay to the east lie acres upon acres of subsided agricultural fields that must be dealt with before the water can be allowed to rush back in.

continued on back page

SPARTINA

The Battle for Native Cordgrass

JACOBA CHARLES, REPORTER

Now in its 17th year of monitoring and treatment, the San Francisco Estuary Invasive Spartina Project remains a uniquely ambitious invasive plant removal effort: from its timeline (indefinite) and size (covering 70,000 acres with more than 150 landowners and managers) to its budget (about $50 million to date) and use of technology (genetic testing, GIS, airboats, helicopters). It's been an effective one, too, reducing stands of invasive cordgrass in the region to a tiny fraction of what they once were.

"We are excited at the continual progress over two decades, even with all the permitting and pandemic challenges," says project manager Marilyn Latta of the California State Coastal Conservancy, which manages the Invasive Spartina Project (ISP) in partnership with the US Fish and Wildlife Service.

The ultimate goal of all this work is to replace invasive cordgrass species with the native one — a distinction that untrained eyes are sometimes unable to make, though the invasives play a very different role in local ecosystems. Found everywhere from upland areas to oft-inundated mudflats, patches of invasive cordgrass can often be accessed only at certain times of day, when the tides are right. And even then, crews require specialized equipment to access eradication sites.

Civicorps Training in February 2023. Photo: Claire Meyler

There are four different invasive cordgrasses in the San Francisco Estuary — all of which are treated by the ISPbut by far the most problematic is a hybrid between native Pacific cordgrass (Spartina foliosa) and non-native smooth cordgrass (Spartina alterniflora), which was introduced from the East Coast in the 1970s as part of early Bay restoration efforts. The hybrid grows taller, more densely, more aggressively, and in a wider range of conditions (from mostly submerged mudflat to mostly dry marsh and upland transition zones) than all other versions of the invader. Where it grows, it destroys habitat that native plants and animals depend on.

Since 2005, the ISP has been methodically using high-tech tools to identify stands of intruders and hybrids, and eradicate them with carefully targeted herbicide treatment. It is a continual battle pitting a broad network of staff and stakeholders of the project against the plants' rapid spread.

Challenges and Progress

This year, 20.5 net acres of invasive cordgrass have been detected within the San Francisco Bay's marshlands, down from more than 800 net acres at the treatment outset in 2005. The bulk of those remaining acres are in areas that were closed to invasive cordgrass removal in 2011 due to federal concerns over the endangered California Ridgway's rail.

However, the initial closure to protect the rail was much more extensive. The last five years have been spent gradually phasing in cordgrass treatment across roughly half of the marshland that had been included in the initial closure area

Treatment near Bair Island with airboat. Photo: Drew Kerr

— while monitoring rail numbers. The results from those areas have been positive: rail counts have held steady, while invasive cordgrass has dropped dramatically and rapidly. "In just a few years, we've seen a more than 80% reduction in invasive Spartina at many of those phased sites," says Latta.

The project is consulting with USFWS for a new permit in May and Latta is hopeful that additional areas will also have their treatment restrictions lifted, allowing a phased approach including treatment, revegetation, and rail protections and monitoring. "We're at a critical point, because the invasive [cordgrass] continues to pump out seed to all the areas we've already treated," she says. "If we can't complete this effort, all of the other restoration is at risk."

Once the initial restricted areas were opened up, progress was rapid, benefiting from myriad incremental advances in methodology accrued during the projects' two decades.

Each marsh is unique in terms of access, hydrology, elevations, and other species that are present. Beyond the physical site logistics, the methodology and technology (such as GIS software and field applications) have also advanced over time.

While simple changes, like whether each day's GIS field data uploads remotely in real time, or needs to be manually uploaded from the office, have greatly improve workflow, there have also been more sophisticated improvements.

"This project stretches the boundaries of the tools and products we use," says Latta, adding that the project's GIS manager Ingrid Hogle has worked with the engineers at ESRI to modify and tailor the software and the GIS tools to better fit the program's needs.

Some tools, such as ISP's custom code to run data analyses in the field, using genetically-verified reference information to provide an identification, did not exist at all at the outset of the ISP.

Another improvement uses specialized small-gauge, low-pressure "Intelli-spray" reeled hoses allows more efficient, targeted herbicide application at a greater distance from the staging area.

Side Projects

By 2019, 14 years into treatment, the ambitious initiative had branched out into many new frontiers, thanks in large part to a grant awarded by the San Francisco Bay Restoration Authority and administered by the California Invasive Plant Council (Cal IPC), an Invasive Spartina Project partner. Among other things, that funding supported a two-year project in which the Invasive Spartina Project served as a nexus for Conservation Corps workforce trainings, led by Cal-IPC and other ISP partners such as East Bay Regional Parks and Midpeninsula Regional Open Space District.

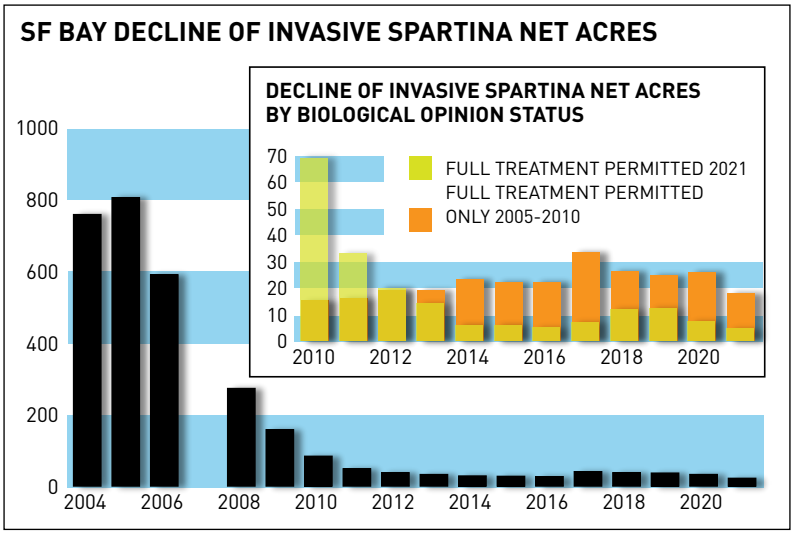
The trainings provided crews with contextual information about habitat restoration and invasive plant treatment, says Claire Meyler, the training coordinator with Cal IPC. "We would talk about Spartina really as a springboard to talk about bigger picture ecological ideas — like the importance of protecting the Bay and the danger of invasive plants," says Meyler.

Replanting with native cordgrass. Photo: Dorothy Aldridge

"These trainings have been huge," Latta adds. "It's great to get younger and [more] diverse and underserved community folks out in the field to receive job training on Bay ecology and wetlands."

This training can serve to transition the participants from manual labor to informed, empowered crews.

"The crew leaders felt a lot more confidence," says Cal-IPCC's Claire Meyler, who led the trainings. "A lot of the times they can feel like they're hired hands, doing work where they maybe don't understand the whole frame of reference as to why we do this. This gave them more [tools] think in those bigger terms about what it takes to actually make a plan to manage invasive plants in a landscape."



And since trainings were conducted by professionals working in the field, they offered direct access to potential mentors and other connections for trainees who might be interested in pursuing a career in the field.

"It's not easy to get into any career, and this career is not the most well known," says Doug Johnson, director of Cal IPC. "By integrating with [professional partners], the crew members were learning directly about land management locally, from people who are working in it professionally."

Back to the Baseline

Despite all the new avenues of implementation for the Invasive Spartina Project, the leaders and crews have never lost sight of the need to ensure they are actually benefiting the species and habitat they set out to save.

An important monitoring effort to evaluate this impact was also funded by the San Francisco Bay Restoration Authority grant. Point Blue Conservation Science was enlisted to update to the bay's California Ridgway's rail population estimate, which found that the bays rail count has increased by roughly 200 birds since 2009-2011, the last time a baywide estimate was conducted. These counts are particularly critical to the ISP as concerns over rail populations are what led to some treatment areas being closed to the project in 2011.

Abundance of these rails is estimated via a formal method of call counts at select sites, during breeding season. The new report, which was released in January 2023, covers 2019 through 2021. In the new survey, methods were revised to be more closely aligned with the North American Secretive Marsh Bird Monitoring Protocol, says Latta.

"These survey results and the substantial revegetation of native Spartina and other native species make me hopeful that we'll be able to get approval to continue treating the remaining areas," says Latta.

Looking ahead, Latta says that she sees a steady march to an actual finish line. If phased treatment is approved at remaining sites in 2023, she is optimistic that detectable invasive cordgrass might be eliminated within the next decade. After that, the hope is to transition to long-term monitoring by individual landowners.

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HERON'S HEAD

Eroding Bayview Park Gets Heavy Lift

ARIEL RUBISSOW OKAMOTO, REPORTER

Carol Bach, who oversaw the restoration of a sliver of tidal wetlands on San Francisco's industrialized shore in 1999, was alarmed to see her work eroding away decades later. Waves crossing the Bay from Hayward to Heron's Head steadily carved away at this small peninsula of tidal habitat and public park favored by locals with few other options for waterfront recreation. The erosion was hard to miss: steep escarpments developed along the shore; the size of the marsh shrank; a tidal pool favored by shorebirds breached and became an embayment.

"We wanted to stop the erosion, restore the tidal pond, and protect the whole landscape using natural infrastructure," says Bach, who stuck around long enough at the Port to fix the problem 20 years later. "But we couldn't go with a green-only, vegetation-only shoreline resilience solution; the erosive forces at the site were too strong."

Adds Eddie Divita, an engineer with Environmental Science Associates who helped design the project, "The landscape at Heron's Head is strange, it's not a natural form but a peninsula constructed out into the Bay with no local sediment supply. Our design goal was shoreline protection that would last 30 years."

Their solution — incorporating coarse beach, two groins, three headlands perpendicular to the shore, 60 subtidal oyster reef balls, and a resilient coastal plant species called seablite — is a grey-green mix of infrastructure that showcases critical options for many eroding sites along the bayshore as sea level rises. "The idea is a vegetated beach protecting interior wetlands," says Bach.

A centerpiece of the design is a two-part beach. On the east end farthest out in the Bay, where the waves roll in, lies a "feeder beach." This beach offers a long-term local supply of coarse gravel to the second beach farther inland. (Managers sourced the material from adjacent Martin Marietta, a sand-mining operation.)

"With constructed beaches, there's often a maintenance problem," says Divita. "If there is no natural sediment supply the beach washes away, especially if it's at an angle relative to incoming waves like this one."

Construction of groins and headlands at Heron's Head in November 2022. Photo: Port of SF

The port completed construction of the project in December 2022, just before the first round of atmospheric river storms over the holidays. "When that storm train arrived, I had many sleepless nights worrying it would wash all our work away," says Bach. But to her delight, the project elements — beach, groins (barriers made of bigger rocks), headlands (barriers made of smaller rocks), a fortified tidal pool — performed exactly as designed.

"In early pictures, the groins look like big ugly scars, but after the first heavy-duty storms the coarse beach material washed east to west over them and now they look more natural. It held up really well in extreme weather," says Bach.

"We wanted to make sure that we had enough speed bumps to keep the gravel on the beach during storms and for a longer period of time," says Divita. Subsequent storms and large waves proved how dynamic their nature-based design could be: "The waves pushed the gravel up the beach slope, actually helping to build up the beach, instead of eroding the tidal marsh," he says.

The original design included five groins made of rip rap and football-size cobbles, and 100 oyster reef balls. But the San Francisco Bay Conservation and Development Commission, which regulates fill of the Bay, didn't like the footprint. As the project made its way through the regulatory approvals process—the third to use the newly improved and more coordinated process called BRITT—three of the groins became smaller "headlands" and the number of reef balls shrank to 60.

"As built there are not enough oyster reef balls to act as offshore erosion control, but enough to serve as habitat for oysters," says Bach. One promising aspect, however, is that the Heron's Head oyster population is expected to be less susceptible to die-offs from excessive freshwater outflows from the upper Estuary. As such it can provide a more resilient source of seed oysters for the Bay in general.

Though the regulatory approvals took 1.5 years to acquire, crews from contractor Dixon Marine built the project itself in just under four months. Bach calls this "miraculous," given the limitations on which months and times of day and tidal windows in which they could work, driven by endangered species protections and access requirements for big equipment.

"Heron's Head is a unique example of nature-based solutions to sea-level rise, including both habitat and rip rap," says Bach. "We need a lot of tools in our adaptation tool box. Not every tool will work in every shoreline."

This shoreline has another special asset: youth from Bayview-Hunter's Point worked as eco-apprentices to grow the seablite in a nursery and plant it on the high beach elevations. "Unlike many wetlands, Heron's Head is very visible to people," Bach says. "It's a place where lots of people can do hands-on restoration."

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SAN MATEO CREEK

A Steelhead Renaissance

CARIAD HAYES THRONSON, REPORTER

Rich Johnson steps though an inconspicuous gate between two backyards not far from the downtown San Mateo Caltrain station and points down a steep, overgrown streambank to a piece of PVC piping, barely visible beneath the tumbling water. "That's our furthest downstream PIT array," says Johnson, an aquatic biologist with the San Francisco Public Utilities Commission (SFPUC). The Passive Integrated Transponder array is one of four stations along San Mateo Creek that capture signals from tagged steelhead as they migrate up and down the creek.

More than a month after a series of atmospheric rivers deluged the Bay Area in January, San Mateo Creek is still running high, fed by unusually large releases from Crystal Springs Reservoir. The high flows have prevented Johnson and his team from replacing damaged equipment, and delayed their annual fish spawning survey. Nevertheless, says Johnson, "I think there have probably been adults coming upstream" from the Bay. The return of steelhead to the creek is recent, and a testament to the power of freshwater flows to restore native fish populations.

The creek, which descends alongside several roads through affluent Hillsborough before mostly vanishing beneath the streets and buildings of urban San Mateo, is little known to most local residents. Unlike some other Bay Area creeks, no "Friends of" group picks up trash from the channel or pulls invasive plants from its banks. Few of its neighbors have an inkling of the minor miracle occurring under their noses.

Creek snorkel survey. Photo: Brian Johnson

In the late 1880s, the Spring Valley Water Company dammed the creek to create Lower Crystal Springs Reservoir, blocking access to the upper watershed for migrating fish. In addition, "Spring Valley bought up all of the water rights downstream from the landowners so that Spring Valley wouldn't have to release any water," says SFPUC's Tim Ramirez (the City of San Francisco bought Spring Valley in the 1930s). For more than 120 years, the only releases from the dam were when it spilled over. What water remained in the creek came from rainfall and runoff from landscape irrigation, and was too warm for cold-water fish such as *Oncorhynchus mykiss* — steelhead and their freshwater variant, rainbow trout.

Rainbow trout and steelhead are genetically identical, but while rainbow live their whole lives in the creek, for reasons that are not fully understood, some juveniles transform physiologically and behaviorally into anadromous steelhead, migrating to the ocean for most of their lives before, ideally, returning to the creek to spawn. "You can have two identically sized fish, and one will be a rainbow trout and the other will be losing its stripe and turning into this beautiful, silvery steelhead," says Johnson.

Steelhead smolt. Photo: Rick Johnson

Steelhead were federally listed as endangered in the 1990s, and in 2010, construction to improve the dam triggered consultation with resource agencies. The resulting Biological Opinion required SFPUC to begin water releases to the creek to restore native fish populations. The new flow releases started in January 2015, and the number of resident fish began to increase almost immediately. Within a couple of years, steelhead redds (egg nests) began to appear.

Two years ago, Johnson's team spotted an adult steelhead, the first such sighting in the creek anyone can remember. But there is plenty of evidence that more are there. A few miles upstream from the PIT array, Johnson points out the best spawning habitat on the creek. "We call it the honeypot," he says. "When the water is lower we can see redds there. Some of these redds are pretty small; those are from resident trout. But some are really very large, like two meters. That's an adult steelhead doing that."

Apart from a tiny wetland just below the dam that was created to benefit two other local endangered species, red-legged frogs and San Francisco garter snakes, SFPUC has done very little in terms of habitat improvements in the creek channel. Johnson says it would be nice to add some fixed, large woody debris and big boulders to create deep pools for larger fish, but on the whole, conditions in San Mateo Creek are quite favorable to fish, and since the releases from the dam began, the population of *O. mykiss* has swelled.

"It's like night and day," he says.

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HABITAT, *cont'd from page 32*

Finding the balance of habitat and water needed for a healthy ecosystem is the holy grail of restoration in the Estuary. The Bay-Delta Plan calls for doubling wild salmon populations relative to the 1967 to 1991 average; the VA's target is to restore 25% of the habitat needed to meet that goal by the end of its eight-year term. The draft science basis report evaluated the effect of the agreement on spawning and rearing habitat in the American, Feather, Mokelumne, Sacramento, and Yuba river watersheds and concluded that although habitat would increase under the VA, the program would not meet its target for rearing habitat in three of the five watersheds. Spawning habitat would meet the target in all the watersheds whether the VA is implemented or not. (The Mokelumne watershed already exceeds 100% for both types of habitat.)

Underlying the VA proposal is the assumption that physical habitat in the Delta is a limiting factor for salmonid populations. However, says BayKeeper's Rosenfield, "We have research that shows that at current levels of flow, and current levels of returning adults, the habitat we already have in the Delta is not limiting. It's not occupied in most years, so creating more of this habitat is not expected to do anything."

Another hypothesis built into the voluntary agreement proposal is that restoring tidal marsh will benefit native fish by exporting zooplankton like copepods, small crustaceans that are a mainstay of fish diets, throughout the Estuary. But, in keeping with previous research addressing this question, a 2022 study led by San Francisco State University biologist Rowan Yelton found that a restored tidal marsh in the Delta did not provide a net delivery of copepods to a nearby channel. "The idea that tidal wetlands export copepods to adjacent areas is not supported," wrote Yelton and his co-authors. "No study yet has found a persistent export of zooplankton from wetlands to open water in the San Francisco Estuary or, as far as we know, anywhere else."

DWR's Conrad notes that even if they don't export zooplankton, shallow-water habitats like wetlands and floodplains are "more likely to be productive of other types of fish food, such as drift invertebrates." This also benefits native fishes, she says.

A different multi-year study published in 2017 by Department of Water Resources environmental scientist Lynn Takata found that Chinook salmon raised on floodplains had an increased growth rate. However, there was no evidence that restoring floodplains would boost salmon populations. "Despite the known growth advantages of floodplain rearing, we did not detect significant differences in survival to the ocean fishery between releases in the Yolo Bypass and the Sacramento River," wrote Takata and her co-authors.

"Failure to find evidence is not the same as disproving a hypothesis," Rosenfield allows. "But if we're banking an entire program on less flow, we'd better know that more habitat works and we don't have that." In contrast, he continues, "we know flow works."

But survival isn't the whole story, says Conrad. "Life history diversity is a key factor for population viability of salmon, and it is related to habitat diversity. When you have increased diversity of habitats, you build resilience into the population," she says. "I think that we are on very firm ground to say that by restoring access to floodplains we are supporting outmigration to occur in a way that [gives fish] more options, so that it's not a simple firehose," pushing fish out through the Estuary to the sea.

Everyone seems to agree that flows and habitat improvements need to go hand in hand for ecosystem restoration to succeed. "It's not enough to have flow without habitat. It's also not enough to have habitat without flow," says Conrad. "The voluntary agreement proposal as a package is trying to meet both of those needs."

The sticking point is whether the VA will provide enough water to make habitat restoration successful.

"You need to put flow down the river to make restoration work," says Julie Zimmerman, who directs The Nature Conservancy's Science for Water Program in California. Habitat and flows work hand in hand, she says, adding that one issue is how the VA defines habitat. "They're defining habitat as simply depths and velocity of water, and it's more than that. When you create habitat with flow, there's a lot more going on," she says, citing the effects of flows on temperature, gravel flushing, and sediment deposit. "We need to start with these functional flows and then shape the habitat to support them. With the voluntary agreements, there's not enough water to do this."

The scale of the habitat improvements in the VA are also a concern, says Zimmerman. "The basic river ecology concept is that flow is the master variable of a river," she says. "If you put flow down a river, you're affecting all these different ecosystem processes, and you're doing it everywhere. [But] when you go out with a bulldozer and you create habitat, you're [mainly affecting] this one little parcel in one place in the system. Even if habitat was limiting, the scale of it relative to the whole river isn't enough to change the trajectory of a population."

The water contractors' Pierre believes that implementation of the voluntary agreement may provide for new scientific insights. "I'm hoping that this is enough of a resource for us to really start to test some of our hypotheses, to understand what are the effects of restoration on its own, as well as the effect of restoration combined with targeted flows," she says.

Jeffrey Mount, a Public Policy Institute of California geomorphologist specializing in rivers and wetlands, also says the science supporting the voluntary agreement proposal is lacking. But, in the face of tremendous pushback on environmental flows from water users, he supports the concept of a collaborative approach that integrates flows and habitat. "We think voluntary agreements are the way to go," he says. "Just more water for fish is not enough. The only way to manage risk is to take risks—you can't set rigid flow standards that won't make anyone happy; you need to manage them as a package with physical habitat."

The science basis report concluded that the combination of flows and habitat restoration proposed in the VA "is expected to improve conditions for salmonids and other estuarine species," while noting that the "actual outcomes...are not certain at this time," due to "uncertainty arising from assumptions and simplifications." The Board held a public workshop on the draft on January 19. Staff are now reviewing comments and revising the draft, which will undergo independent peer review before becoming final.

Reporting support by Robin Meadows.

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DAVENPORT, *cont'd from page 21*

San Francisco Bay Shoreline ecotone levee in San Jose and the Terminal 4 green seawall in Richmond.

Both agencies, along with the U.S. Environmental Protection Agency, are also funding a big push for programmatic approach to living shorelines to expedite permitting and design for ten projects at once, through the Regionally Advancing Living Shorelines Project led by the Conservancy and the San Francisco Estuary Institute (SFEI). These projects include subtidal habitat restoration of oyster reefs and eelgrass, which also attenuate wave energy.

Flood Control 2.0

Another growing trend is restoration where creeks meet the Bay. As part of implementing the recommendations of SFEI's Sediment for Survival report, agencies are planning to connect watersheds to marshes for sediment replenishment through project like the Calabazas/San Tomas Aquino Creek-Marsh Connection Project in the South Bay and Evolving Shorelines at Bothin Marsh in Marin, which will reconnect Coyote Creek to the marsh.

In a similar vein, many projects are implementing a strategy dubbed Flood Control 2.0, which combines restoration and flood protection at creek mouths. Examples include Lower Walnut Creek in Contra Costa County, Colma Creek in San Mateo County, Lower Corte Madera Creek in Marin, and San Francisquito Creek on the border of San Mateo and Santa Clara counties.

Scaling Up

Finally, another exciting development is landscape-scale restoration strategies and projects, including efforts to address the challenges of protecting or redesigning infrastructure and other land uses that conflict with ecosystem functions. The Bay Area already has made major strides in this area, such as the completion of the Napa River Salt Marsh Restoration Project, which restored 10,000 acres of former salt ponds, remnant sloughs, fringing marsh, and levees to tidal marsh and other valuable habitats in the North Bay. The project also provides wildlife-oriented public access in what is now the Napa-Sonoma Marshes Wildlife Area.

The South Bay Salt Ponds Restoration Project, at 15,000 acres, completed Phase 1 and Phase 2 is well underway. The Suisun Marsh Plan, completed in 2014, is a 30-year plan that balances the enhancement of 40,000 acres of managed wetland habitat with restoration of 5,000-7,000 acres of tidal marsh. More recently, in 2020, Sonoma Land Trust completed the Sonoma Creek Baylands Strategy, which addresses the constraints to restoration imposed by Highway 37 and SMART rail, as well as providing an innovative vision of how to make the best use of existing sediment when restoring tidal action to large portions of this 35,000-acre planning area, much of which is already in public hands. A similar effort, the Petaluma River Baylands Strategy, is expected to be completed in 2023.

Never Satisfied

Looking back on my 16 years of involvement in restoration in the San Francisco Bay-Delta Estuary, I've noticed that this community is never satisfied and keeps raising the bar on the definition of what makes a good or a great restoration project. Faced with the whipsaw conditions of droughts and floods, growing income inequality, and ongoing racial injustice, we refuse to retreat into hopelessness or isolation. Instead, we are asking harder questions, reaching out to form new partnerships, and, in return, being restored ourselves by the work we do.

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One of the most ambitious and successful flood control projects in the region to date created much more space for water to spread out from the Napa River. The project has performed admirably in subsequent storms, including recent deluges like the one pictured here in 2017. Photo: Napa RCD

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San Francisco Bay and the Sacramento-San Joaquin River Delta comprise one of 28 "estuaries of national significance" recognized in the federal Clean Water Act. The San Francisco Estuary Partnership, a National Estuary Program, is partially funded by annual appropriations from Congress. The Partnership's mandate is to protect, restore, and enhance water quality and habitat in the Estuary. To accomplish this, the Partnership brings together resource agencies, non-profits, citizens, and scientists committed to the long-term health and preservation of this invaluable public resource. Our staff manages or oversees more than 50 projects ranging from supporting research into key water quality concerns to managing initiatives that prevent pollution, restore wetlands, or protect against the changes anticipated from climate change in our region.
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Saltmarsh baccharis seedling planted at Giant Marsh Living Shorelines Site.

BIRDS, *cont'd from page 10*

"We need restored natural wetlands and bird-friendly agricultural practices that provide varied habitats to support diverse bird populations in the Delta," Dybala says. "The more we address flood protection, water storage, and other basic needs using nature-based solutions, the easier it will be to keep birds off the endangered species list."

"If you build it, they will come"

The dull hum of the freeway makes it across Pond E9 to the monitoring site at Eden Landing, but the random peeps of waterbirds break through. A seal pops up its head in the channel, and a White-tailed Kite hovers overhead.

Van Schmidt uses two hand counters to track about 1,500 American Avocet, 500 Northern Shoveler, and small numbers of Dunlin, Northern Pintail, Dowitcher, Black-bellied Plover, Canada Goose, and Black-necked Stilt. He recalls with amazement a day when he counted 5,000 Ruddy Duck on a nearby pond.

Of course, restoring wetlands isn't just for the birds. The ecosystem benefits include water filtration, flood protection, and carbon sequestration. "Acre for acre, restored wetlands collect a lot of carbon compared to other habitat types in California," Van Schmidt says.

Beissinger says that as sea levels rise in response to climate change, all that water will need somewhere to go. "Restoring wetlands now, so that rising waters have the opportunity to shift as things change, is going to be really important. And, yes, if you build it, they will come. That's one of the nice things about most birds — they fly."

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MUD, *cont'd from page 37*

To help move the project along, the Conservancy recently contracted with an engineering consultant that will lead a series of design charrettes, Davenport says. In addition to evaluating concepts generated through that process, "the Corps will conduct value engineering, a review process that will seek ways to reduce cost while still delivering the desired ecological functions," she adds.

A tentative schedule outlined by the Corps anticipates that plans and permits will be complete by 2026 and a construction contract awarded by 2027. Sediment placement should take place over the ensuing decade, with the big moment — the levee breach — finally occurring around 2037.

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