CALFED BAY-DELTA PROGRAM

NEWS FROM THE CALFED BAY-DELTA SCIENCE PROGRAM

SCIENCE IN ACTION

Puzzling Over the Shallows

Three years ago, "shallow water habitat" was the buzzword of the CALFED ecosystem restoration program, a triplet that conjured up visions of recreating the labyrinth of thriving Delta marshes now barricaded behind levees, and of saving the silvery salmon and smelt that would stream into them to eat, sleep and spawn.

DWR scientist samples larval fish along marsh-edge in Mildred Island.

"CALFED started with the concept that creating various kinds of shallow water habitats would make the ecosystem healthier and lead to a return of native species, but it's much more complicated than that," says Sam Luoma, chief scientist for the federal-state CALFED Bay-Delta Program, which is working to balance competing demand for the Estuary's fresh water with one of the most ambitious ecosystem restoration programs on the continent. "We need to slow down our expectations, manage the Delta for a variety of species, as well as the endangered ones, and try to focus restoration in places and ways that improve conditions and exclude invaders."

CALFED's *Ecosystem Restoration Plan* (ERP) calls for the creation of up to 9,800 acres of a mixture of shallow water habitats (tidal perennial aquatic, shoals, sloughs and mid-channel islands), and another 30,000-45,000 acres of fresh emergent wetlands in the Delta alone by the year 2030 (it also calls for large acreages in Suisun Marsh and the North Bay). CALFED's 2000 Record of Decision is more general, but sets ERP milestones in its biological opinions adding up to 13,600 acres of shallow water type habitats and wetlands within the first seven years of implementation. Beyond CALFED, U.S. Fish & Wildlife's 1996 *Delta Native Fishes Recovery Plan* — aimed at helping Delta smelt and splittail, among other natives — also recommends the restoration and protection of shallow water habitat less than three meters deep. And down in the Bay, the 1999 *Habitat Goals* call for the recreation of over 50,000 acres of tidal marsh in the baylands along the Estuary's shores — to benefit not only endangered clapper rails, harvest mice and other wetland species, but also the ecosystem — within the next few decades.

"There's lots of people on the bandwagon saying we need more habitat, more marsh, more shallows, but little scientific justification yet for what the outcome of creating it will be," says the U.S. Geological Survey's Jim Cloern.

At the most basic level, scientists all agree that the Estuary's shallows, and their fringe of muddy flats and marshy shores, are indeed ecologically important — places where plants and fish grow, eggs hatch, worms burrow, sediment settles and ducks dive and rest. But just which kind of shallows make the best habitat for fish has been harder to map out than say, what makes a good treetop for a spotted owl, or a big enough berry patch for a grizzly bear or the right height creek bank for a riparian brush rabbit. Learning about habitat hip deep in muddy water or thick with tules or down on a river bottom is a much more challenging endeavor involving boats, rubber pants, diving gear, nets and meticulous timekeeping to keep track of tides, seasons and water movements.

As CALFED plans and funds some of the biggest restoration projects to date, it has asked local scientists to come up with a clearer picture of what exactly goes on in the shallows and which flora and fauna, even which basic ecological processes, stand to benefit from its plans to break open the levees of numerous Delta islands and let the rivers and tides reclaim their former domain.

"We forget that the processes that created the marshes over geologic time are not the same processes that will restore them," says researcher Philip Williams, pointing out that sea level rise over the last 6,000 years drowned the Sacramento and San Joaquin river valleys and created the over 500 square miles of marshes and shallows of the 1800s Delta. Even the word "Delta" conjures up a procedural misconception — a vision of the mighty Mississippi

Continued page 2

DEFINITIONS

WHAT IS SHALLOW WATER HABITAT?

Shallow water habitat comes in all kinds of flavors, including shoals around deeper bays, "dead-end" sloughs and tidal, permanent and seasonal wetlands. To humans, perceptions of shallow and deep are dependent on a person's height, according to a recent paper by the U.S. Geological Survey's Larry Brown. Most official definitions run in the less than two-to-three meters deep category, or not so deep that an NBA basketball player in up to the eyeballs couldn't still jump up for air. Human height aside, many definitions better relate to the life history of fish — Delta smelt need shallower areas to spawn than the open bays and rivers where they spend most their adult lives, for example — or to the ability of light to penetrate so that tiny plants can grow (a depth a little over Sam Luoma's head). And don't forget that in a tidal system, what is shallow one minute is deep the next. A national U.S. Fish & Wildlife Service wetlands classification system (1979) says that shallow water habitat in areas isolated from the tides is water two meters or less in depth, and in tidally influenced areas is water two meters or less in depth at lowest low water. In a recent more Bay-Delta-specific paper defining shallow water habitat, the Interagency Ecological Program's estuarine ecology work team expanded the Fish & Wildlife definition to include areas up to four meters deep in the large open waters of San Francisco, San Pablo, Suisun and Honker bays (see iep.water.ca.gov).

Puzzling Over the Shallows

importing vast loads of sediments from the interior and spreading it out at its mouth into the sea.

Our own rivers, backed up behind dams and into narrow channels, now have little sediment to import into the new shallows and marshes everyone is gung-ho to create — sediment these former wetlands may now need to bring them back up to intertidal levels after years of slowly subsiding behind levees. "Building marshes today is a much more sediment-reliant process than it was in the first place," says Williams.

The sediment may be a long time coming in some places, according to new science (see *The Breaching Business*, p.3). As it dribs and drabs into some of our restoration sites and floods into others, as more invasive plants than natives move in to colonize newly created shallows, as food supplies for fish decline and mercury spreads into the estuarine food web (see *Where's the Food?* p.8 and *Mercury in the Mix,* p.6), many scientists are saying that perhaps the time has come to rethink our goals.

"We've learned that for most restoration projects, it's extremely difficult to get back to a predisturbance habitat," says Charles Simenstad of the University of Washington. "In fact, the best we can hope for may be some alternative ecosystem."

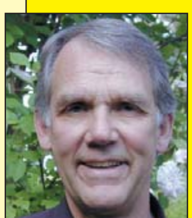
That catchy triplet "shallow water habitat" may be a part of this new ecosystem, but many scientists are saying the term is just too vague to be useful anymore. It's not so much the shallows we want, they say, but something more specific, like a shoal or a slough or a salt marsh, or something more complex, like a mosaic of these habitats.

In the meantime, the puzzles in the shallows abound. Just breaching a levee and getting an instant great marsh, as happened at the famed Carl's Marsh off San Pablo Bay (see p.7), may not be the norm up and down the Estuary. So where are the best places to breach? How much can we rely on sediment and how much on vegetation to build the marsh? If new marshes are filled with invasive plants and fish, will they still have some habitat benefits to the natives? Will flooding all these old farmfields make more food for fish or not, and in which seasons? Or will it just release more mercury into the food web? Is it a better bet to build a gravel bed in a creek, tear down a dam, supply more spring flows or allow more seasonal flooding than to try to bring back the Delta's once-vast shallows? Many of these unresolved issues were no surprise to CALFED and figure prominently in its *Ecosystem Restoration Plan.* And as a result of its investment in a whole new wave of interdisciplinary restoration science, answers to some of these questions are slowly emerging.

"This messy circumstance in the Delta is not unique; there's nowhere on the globe where we've got this puzzle solved," sums up Cloern. "What we're doing here is the leading edge, brand new environmental science. It will be we that provide models for the rest of the globe about how to apply science to making environmental decisions."

Mildred Island

OUTLOOK



A YOUNG SCIENCE: LEARNING AS WE GO

SAM LUOMA
LEAD SCIENTIST
CALFED

"Restoration is a very new science, perhaps no more than two decades old. It started with intuition, with the idea that we could just define what we wanted and then go out and restore it. But the thought that we could just turn the Delta into all this thriving shallow water habitat was too simplistic. The new scientific findings provide a reality check.

"One of CALFED's priorities is to make sure restoration uses the best available science. We've learned several key things in the past three years. First, we've done the math on sediment supply and demand, and we have learned that supply will be a challenge in returning vast reaches of the Delta to marshes. This is the first time we've put real numbers into the sediment equation. People are now working to solidify those numbers. Second, we've learned a tremendous amount from looking at all the 'restoration' of shallow water habitat that has already happened as a result of natural or accidental levee breaches (see p.3). Looking at how the breach sites have evolved historically will help us more clearly see the range of possible outcomes of our own restoration efforts. Third, we've learned that it will be challenging to predict what will happen, at least at our present state of knowledge. This Delta system is more complicated than anyone originally thought. We must learn all we can from our successes, and even more so from the restoration projects we may be disappointed with.

"Looking ahead, I see several key tasks before us. First, we need to continue our new multi-disciplinary approach to restoration science so we can better understand the links between hydrodynamics, ecology, chemistry, geomorphology and biology. Taking this kind of approach in our study of places like Franks Tract and Mildred Island has really paid off (see p.10). Second, we need to learn more about the links between exotic and native species, and how exotics impact different kinds of organisms. Third, we need to develop a much more detailed understanding of the life history of the fish we are trying save, what their habitat needs really are and what truly threatens them. Part of this will mean investing in analysis of data we already have. Creative solutions to ecosystem restoration will come from better knowledge in these areas."

RESEARCH

The Breaching Business

Scientists have been wading out into shallows all over the Delta and Bay seeking insight into what really happens when we breach a levee to restore a former marsh: how much sediment settles in or flushes through, what kinds of plants grow and how fast, what kinds of fish use the new habitat and how much can we rely on nature to do the restoration work? CALFED has funded two "BREACH" studies — one comparing breached levee sites in the Delta, and a newer one now underway examining sites further downstream in Suisun and San Pablo bays. Results to date provide new clues about what to expect from shallow water habitat restoration.

The first set of BREACH studies, conducted between 1998 and 2000 in the Delta, analyzed six shallow water sites with historical levee breaches in order to predict the feasibility, patterns and rates of restoration to natural ecological function. The six sites ranged in age from 13 to 67 years since breach, and in subsidence levels from 1.1 to 2.3 meters below sea level.

Some of the sites resembled large lakes (like Mildred Island, an expanse of open water ringed by levees); some featured tule marshes (such as Donlan and Venice Cut islands, whose elevations were already intertidal at the time of breaching or had been artificially raised with dredged material); and some were in the more intermediate stages of wetland development (Old Prospect Island). Researchers also hunted down four remnants of Delta wetlands that had never been completely enclosed by levees to serve as reference points for comparison to historic conditions.

"This was a whole new approach for the Bay and Delta region," says BREACH studies team leader Charles Simenstad of the University of Washington. "Nobody had ever really looked at naturally breached sites for insight into where we were headed."

To evaluate restoration trajectories at these sites between February 1998 and December 1999, the BREACH I research team undertook an integrated approach — combining the analysis of historical data and photographs with field work to see what was actually happening down in the shallows and oozes. Methods included applying GIS to aerial photographs; following up with ground truthing and shoreline transects to assess marshplain development; conducting high-resolution GPS surveys; sinking sediment and benthic cores; and trapping insects and fish.

First up was an attempt to create conceptual model of how the breached levee study sites evolved over time, an analysis by Philip Williams and Michelle Orr of Philip Williams & Associates and the University of New Orleans' Denise Reed. The model suggested that sediment accumulation in deep, open water areas initially appears to outpace rates of sea level rise, then slows. The slow-down occurs because after the first gush of sediments and water into the site from the breach, the amount of sand and mud floating in the water column diminishes and what's left, and what's on the bottom, keeps getting stirred up by waves.

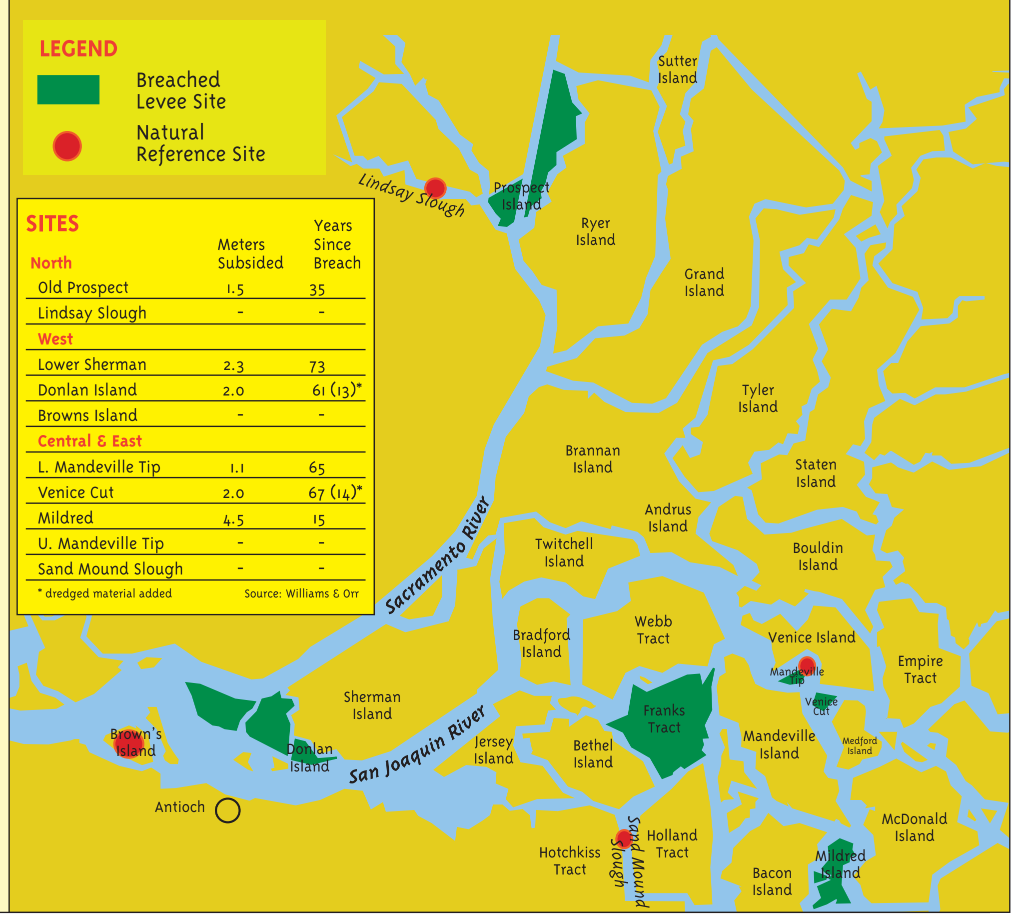
So depending on local conditions, sediment build up at some sites may continue to outpace sea level rise (especially if vegetation gets established), while at others it may not.

Mildred provides a good case in point. To figure out how much sediment the island had accumulated since its 1983 breach, Orr sunk a core to the point of resistance (which researchers assume is the level of the original pre-breach farmfield, where the soils are harder and more compacted), then measured the depth, which turned out to be 0.64 meters. Averaged out over the years, Mildred's annual rate of sediment build up came out to 47-51 mm, though Orr thinks a sizable part of this resulted from the first post-breach gush. A look at historical data from Rhode Island confirmed a similar rate.

"Even though we've seen about two feet of accreted sediments at Mildred, this data is telling us that the system is heavily subsided, that a return to tidal elevations may take a century or more, and might never happen,

Continued page 4

BREACH I STUDY SITES



SITES

	Meters Subsided	Years Since Breach
North		
Old Prospect	1.5	35
Lindsay Slough	-	-
West		
Lower Sherman	2.3	73
Donlan Island	2.0	61 (13)*
Browns Island	-	-
Central & East		
L. Mandeville Tip	1.1	65
Venice Cut	2.0	67 (14)*
Mildred	4.5	15
U. Mandeville Tip	-	-
Sand Mound Slough	-	-

* dredged material added Source: Williams & Orr

and that there's no guarantee the site will ever become a marsh," says Simenstad.

Mildred's neighbor Franks Tract is in even worse shape, in terms of its long-term potential to grow tules and cattails. Though Franks was breached in 1938, nearly half a century before Mildred, and though it was much less subsided than Mildred in the first place, there is no evidence that sediment has built up relative to sea level rise since the breach. The problem at Franks is partly related to the waves rolling across its long fetches, which keep resuspending, rather than settling, the sediment. Indeed researchers now believe Franks Tract may never fill in at all, and may have reached what Williams calls an "open water equilibrium." Big Break and Sherman Lake may have also reached this state.

Elevation plays a critical role in what kinds of plants grow on the breach sites. The sites need to be somewhere near tidal levels before marsh plants can begin to take root. The BREACH I conceptual model suggests that pioneer marsh vegetation establishes rapidly (within four years) at elevations around 1 meter relative to mean lower low water (MLLW). Once established, vegetation spreads at lower elevations by lateral expansion from initial patches. This outward expansion proceeds at a slow rate (maximum of 1.5-3.0 meters per year) and requires sheltered conditions with few waves.

"The marsh builds laterally, as well as from the bottom up," says Simenstad, explaining how seedlings take root in the shallows at the edges of a subsided site, then trap more sediments with their roots. "It's a positive feedback loop. Once it's shallow enough for plants to colonize, they build more of their own habitat."

Although the presence of vegetation reduces the potential for scour and promotes additional accumulation, the rate of elevation change can remain very slow. Breached site marshplains that have been vegetated for decades remain well below natural marshplain elevations, according to the BREACH I research. Sherman Island, for example, has had emergent vegetation for over 60 years and remains 0.38 of a meter below Mean Higher High Water (MHHW), or 0.48 meters below the reference site at nearby Browns Island.

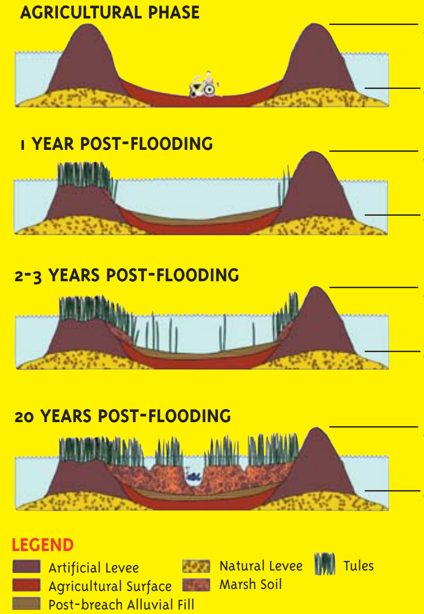
Going beyond the historical and conceptual perspective, Reed took a closer look at current sedimentation rates, measuring build up and erosion at the 10 study sites between March 1998 and June 1999 with various types of cores and markers laid out in controlled plots.

Reed found at least 10 mm, and sometimes more than 20 mm, of accretion during the 13-month period. More accretion occurred between March and August than between August and December, apparently because most of the river runoff and accompanying sediment inputs occur during the late spring and early summer.

The northern sites showed the highest levels of accumulation (up to 40 mm), confirming hypotheses that the amount of tidal energy and sediment supply varies between the North, Central and Western regions, and affects build up. There was little difference in sediment findings for the latter two regions, but a big difference between their levels and the northern site at Old Prospect Island. The key geomorphic factor here, says Reed, is the location of these sites near the base of the Yolo Bypass and the accompanying direct connection to the Sacramento River. The research took place during a time of major flooding in the bypass, mimicking a historic process of big sediment inputs with high storm flows.

Sediment accretion doesn't always equal elevation change. Restoration sites with high rates of accretion rarely showed similarly high rates of elevation change, or rates as high as reference sites, says Reed. "The young developing marsh soils compact more than the more mature older substrates," she explains. One key factor is location on the edges, versus the interior, of the sites. At plots at the edge of the Prospect Island's marsh, almost 40 mm of material accumulated over the marker horizon, while elevation change was effectively zero. But in the interior of the island, a similar amount of accretion resulted in a elevation change of almost 30 mm over the 13 months. The difference may be due to different plants producing differing root structures and properties, or to the supply of heavier sandier material to the edge of marsh.

CONCEPTUAL MODEL OF BREACHED WETLAND



One of BREACH I's conceptual models, showing a restoration trajectory of rapid development of shallow water, emergent marsh. Source: Williams, Orr & Reed
Drafting: Nina de Luca

Another key factor is type and volume of the material laid down on the restoration floor. Reed found very little variation across the Delta in terms of the accumulation of organic material, but a big difference in the accumulation of mineral material, such as that pouring into Prospect Island from the Yolo Bypass. "What we really want, if we want a nice high marsh, is high weight for firm soil and high volume for more soil, and that comes from a high supply of mineral material," she says.

Based on all the research, the BREACH I team projected that restoration projects could expect sediment accumulation rates of 4 cm per year for subtidal habitats and 1 cm per year for intertidal habitats, depending on wave and current energy.

"It was a big thing when we realized that these restoration sites were not going to fill in by themselves," says Reed. "Clearly, restoring Delta dynamics alone will not get us the array of shallow water habitat we think we need. Some structural measures will also need to be taken to build substrates back; otherwise, instead of shallow water, we'll get deep water."

If the water is shallow enough, then the BREACH team fieldwork indicated that tules will grow up within several years, but if it remains subtidal, it will get colonized by submerged or floating aquatic plants,

DWR crew explores fish-habitat linkages using depletion seining inside a block-net enclosure.

like pennywort, or invaders, like water hyacinth, Brazilian waterweed (*Egeria densa*) and parrot's feather. Vegetation surveys of BREACH I sites indicated that all the less subsided (or artificially elevated) areas of Old Prospect, Donlon and Venice Cut islands showed initial rapid tule marsh establishment after breaching or dredged material placement.

"The marshes are only there because the dredged material was placed there, not because they came naturally," says Reed. "It shows us that we don't need to raise sites all the way back to the level of natural marshes to get tules, just kickstart them up to intertidal elevations."

BREACH I sites with subtidal elevations were dominated by invasive aquatic plants, according to the study, raising new questions about whether floating or submerged vegetation helps or hinders the transition from subtidal to intertidal elevations.

Researchers then moved on beyond the mud and plants to see what kinds of aquatic critters inhabit these breach sites. In some cases, they found more benthic invertebrates (clams, worms, etc.) in the oozes of the mature reference sites, but the breached sites had similar species compositions, indicating their potential to contribute to the emerging wetland food web. However, insects falling out of the emergent vegetation were often more dense in the restoring sites than in the mature reference sites. There were also distinct differences in densities and types of insects and invertebrates living in the emerging tule marshes from those in exotic and native floating vegetation. A comparison between water hyacinth and native pennywort by the University of Washington's Jason Toft found higher densities of the amphipods and macroinvertebrates favored by hungry fish in the pennywort, largely due to differences in habitat architecture — the hyacinth was taller and covered more surface area, reducing dissolved oxygen levels in the water for fish.

All of the information on elevation, vegetation and food offers building blocks in answering the final, and perhaps central, question of the BREACH I studies — are these flooded tracts good for fish? The Department of Water Resources' Lenny Grimaldo and his colleagues set out to determine if fish species composition in three of the sites — Mildred, Lower Mandeville Tip and Venice Cut — was in any way related to the age of the wetland, its status as a breach or reference site or to physical attributes within the sites (e.g., vegetation structure, water temperature, salinity, water clarity, etc.).

To find out, he set up fish enclosures 30 by 49 square meters in size and used block nets and beach seines to catch juvenile fish in intertidal and nearshore areas, and purse seining to sample deep subtidal areas inaccessible by wading. Researchers measured environmental variables before, during and after each sampling event, and surveyed vegetation. During the 16 months of the study, they collected a total of 47,138 fish representing 32 species. The five most abundant species, comprising 90% of the total catch, were threadfin shad, inland silverside, redear sunfish, bluegill and largemouth bass. The most abundant natives, only 2% of the catch, were tule perch, splittail, chinook salmon and prickly sculpin.

According to Grimaldo, the results confirm what other studies have before them — that introduced fish easily colonize and dominate these new habitats. But he also discovered that native fish turned up in all habitat types — from those with open waters to those with dense submerged aquatic vegetation. This suggests that restoring just one habitat type cannot be expected to recover all native fish, he says. It also suggests that there may be some habitat trade-offs between breached wetland restorations of different elevations.

"Introduced species are so established it's hard to tease out what's actually good for the natives," says Grimaldo. In the BREACH I studies, Grimaldo did find some clues in the seasons and water temperatures: native fish spawned and reared at the study sites during an early window in the spring under a cool temperature regime, ranging from 10-18°C. In contrast, introduced fish spawned and reared from late spring to early fall, when temperatures were warmer, ranging from 15-25°C. "We may need to take advantage of opportunities to restore wetlands at certain elevations that flood in the spring when the natives spawn but not during the summer when the non-natives

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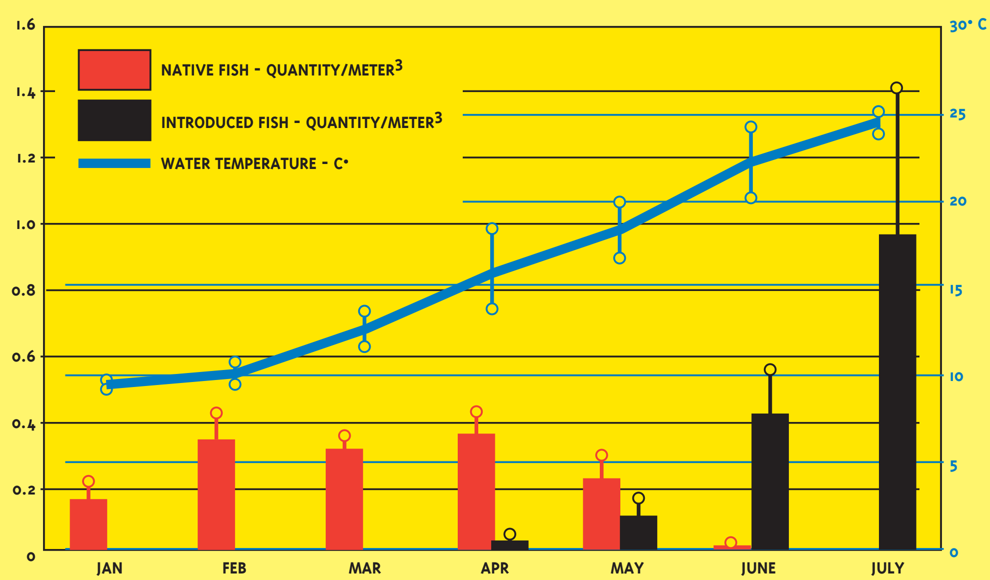
RESIDENT LARVAL FISH DENSITIES
COLLECTED IN CENTRAL DELTA DURING 1999



Source: Grimaldo

The Breaching Business

spawn," says Grimaldo. Other research has already shown that seasonal flooding of large floodplain areas like the Yolo Bypass favors native species, like splittail, better adapted to winter flood extremes.

Grimaldo says there's a lot of uncertainty about increasing native fish populations through habitat creation — because the Estuary's hydrology is so permanently altered, and natural variability in flow conditions — which strongly influence natives — cannot be replaced. For example, though there were more native fish at the reference sites, they were much more influenced by the water temperature and vegetation than by the age of the wetland. "Restoring marshes to intertidal levels is not the only endpoint; another important endpoint is increasing natural variability," he says.

Getting a better grip on the impacts of exotic plants might help too. The presence and density of submerged aquatic vegetation does influence the lives of fish, according to Grimaldo. These underwater plants provide both benefits (food web support) and problems (obstacles) for fish, depending on the size of the fish and the density of the plants. Many of the breach sites are so subsided and so deep that they make perfect habitat for invasive *Egeria densa*, which can become so thick that it creates a wall between deepwater and intertidal habitats that growing fish cannot maneuver in. This may constrain salmon, for example, into deeper channels where there's less to eat and higher risk of being eaten — as explored in a tandem predation study.

"The proliferation of *Egeria densa* in subtidal habitats in the Delta has probably had one of the biggest effects on fish habitat and assemblage structure in the region," says Grimaldo.

In sum, the BREACH I research suggests that more opportunistic fishes will benefit from early restoration phases, while fish with more restricted habitat and food preferences may benefit from later-stage intertidal habitats.

We may have to face the fact, sums up Simenstad, that in these Delta breach projects, remain deep for so long, "we're ending up with an early stage habitat we don't want or a habitat for introduced species. So there's an implicit ecological trade-off to strategies that promote large areas and long periods of the subtidal phase of habitat restoration."

CONTAMINANTS

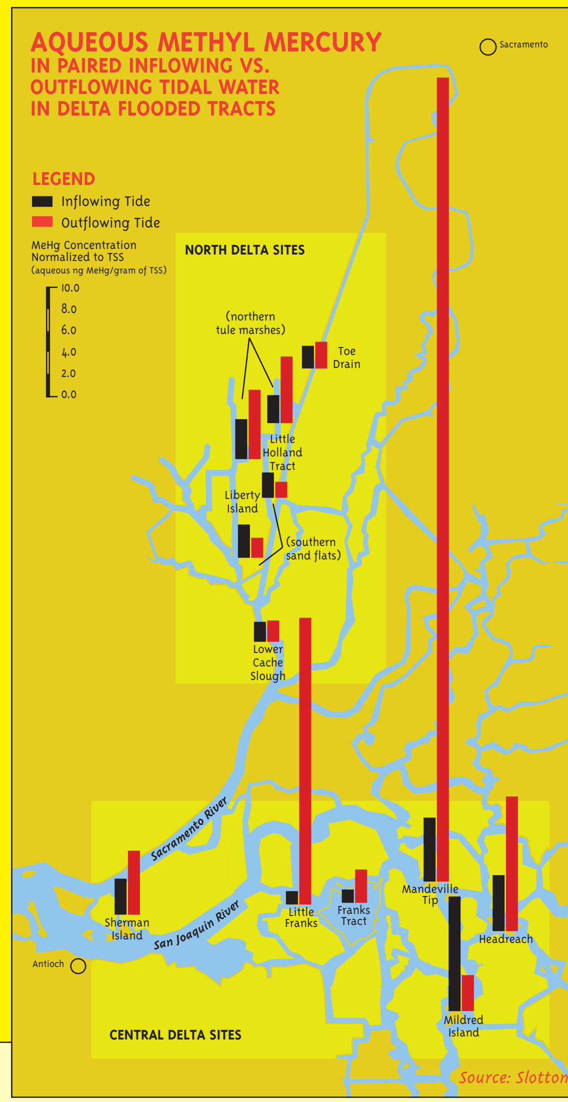
MERCURY IN THE MIX

The fact that flooding big island tracts and restoring tidal wetlands could be boosting mercury inputs into the estuarine food web has not escaped CALFED. In its effort to take an integrated approach to restoration science, CALFED has supported a multi-agency, multi-year mercury research effort, the first years of which have already pinpointed mercury hot spots in the Delta (Cache Creek, Cosumnes and Yolo basins), and the more recent years of which have been examining the effects of wetland restoration on mercury methylation. Mercury is a trace metal once widely used in Sierra gold mining, and widely mined itself in the Coast Ranges. As a result, mercury is now widespread in Bay and Delta sediments. Wetland processes can promote the methylation of this mercury, transforming it into a chemical form more easily taken up by clams, fish, birds and other estuarine life, with potential sub-lethal effects for them and health risks for any humans consuming contaminated fish.

As part of CALFED's mercury research, U.C. Davis' Darell Slotton has generated a number of new findings. Though fish and clams in restoration sites frequently indicate similar levels of mercury as those in off-site channels and rivers, the reason may not be that methyl mercury production is the same everywhere, but that vigorous tidal action is doing a good job of spreading it around within Delta subregions. Preliminary data on the amount of methyl mercury coming in and going out on the tides suggests that restoration tracts, particularly the more mature, highly vegetated ones, may be important localized sources of the metal in its most bioavailable form.

"As far as methyl mercury export goes, the worst kind of habitat we sampled in the Delta was the kind you find at Mandeville Tip, where the tule marsh is just solid. The second worst was the kind at Little Franks Tract, where the *Egeria* is so thick it's like a fish tank chock-full of weeds. Both showed a big response in producing dissolved methyl mercury on the tide and then passing it out into the system," says Slotton. By contrast, Liberty and Little Holland tracts, with their big mudflats, produced a lot less methyl mercury, and the wide-open depths of Mildred actually passed less methyl mercury out into the channels than came in on the tides, he says. One thing still puzzling Slotton is why some of the most extreme methyl mercury export sites among the dozen or so habitat types examined were also in the region where mercury bioaccumulation in silversides, a small fish, were lowest.

Slotton has also sought to respond to those who believe that the raw methyl mercury is just being dragged in and out with the mud, and has nothing to do with the restoration. He experimented with factoring this issue into his data (see map). "If you normalize for resuspended sediment in the water, the mercury levels look even higher," he says.



RESEARCH

Bay Breach Rolls

In 2000, the BREACH team moved down the Estuary to study tidal marsh restoration and processes at 10 sites in Suisun and San Pablo bays. Very early results suggest that North Bay breach sites develop much faster than Delta sites, and that more native species may be using these new habitats.

As in the Delta, the BREACH II study is comparing restored sites with relatively ancient marshes (several thousand years old) and "centennial" marshes (around a hundred years old, and formed with the flood of sediment from the Gold Rush). The main differences with the Delta study sites are starting elevation — Delta sites are subsided up to six meters below sea level, whereas most Bay sites are only a few meters — and rates of sediment deposition.

"Getting the Delta sites back up to tule marsh elevations takes forever, but down at Pond 2A and Carl's Marsh, for example, we've found there's still enough sediments moving around the Bay to see that the elevation debt has measurably decreased over time," says the University of Washington's Charles Simenstad.

No data is in yet on sediment accumulation or vegetation trends, but there are some early samples of fish and birds at the Bay breach sites that suggest they may stack up to the ancient marshes in some ways. San Francisco State University graduate student Tammie Visintainer has sampled fish at the sites during three seasons this year. Based on a back-of-the-envelope look at the April results only, native species made up the majority of the composition at all sites, ranging from 82-100%. Splittail, a threatened native species, were common in some sites. At Suisun Bay's Ryer Island, a 17-year-old restored site, splittail comprised 22% of the total catch, at Sonoma's Carl's Marsh 13%, and at Napa's Pond 2A, a former salt pond, 9%.

"In general, there was a higher taxa richness at the breach sites compared to the reference sites," says Visintainer. Looking at some of the later samplings, she notes that species composition changes greatly with season. For instance, juvenile Pacific herring made up 61% of the total catch at Toy Property (breach site), 99% of the catch at Greenpoint (reference site), 64% of the catch at Petaluma Ancient (ref), and 20% of the catch at Carl's Marsh (breach), but after April, counts greatly diminished at all sites as the herring headed out into the Bay.

BREACH II researchers also surveyed birds at the study sites, and noted a few interesting things. Based on a preliminary look at data from sunrise point count surveys conducted by Julian Wood and Hildie Spautz from the Point Reyes Bird Observatory, the early restoration sites, which still have exposed mud, are more attractive to shorebirds and waterfowl, especially during the migration period, than more mature sites with more vegetation cover. The more mature breached sites, and the reference ancient and centennial marsh sites with tall dense vegetation, support more passerines and other marsh-breeding sparrows, wrens and rails.

"You can see the value of having a mosaic of marsh habitat, with a variety of ages and marsh cover types, including vegetation, ponds and channel systems, from these findings," says Spautz.

According to Simenstad, the emerging differences between Bay and Delta breach study findings suggest somewhat different conclusions about the rate and fate of shallow water habitat restoration. For instance, the role of low suspended sediment sources and wind-generated sediment resuspension that appears to be so prominent in the Delta may not stall the development rates as much lower in the Estuary because many more of these marshes are small sites adjacent to considerable riverine and Bay sediment sources.

While there still isn't any data on the sediment accumulation and restoration trajectories of the BREACH II sites, some sites overlap with work already done by Philip Williams and Michelle Orr, and other lessons learned may weigh in. In a review of the history of 15 re-flooded sites around the Bay, ranging in size from 18 to 220 hectares, and in age from two to 29 years old, Williams and Orr found that 50% cover established at nine of the sites within 20 years, some within just four years, a faster rate of cover than on the Delta sites.

For the Bay, Williams and Orr concluded that three factors retard the timeframe for vegetation establishment: limited sediment supply, erosion of deposited estuarine mud via internally generated wind waves and restricted tidal exchange. They point out that the shorter timeframe for vegetation colonization and marshplain evolution experienced in earlier, smaller and less subsided sites may not necessarily be replicable by simple levee breaching on larger subsided restoration sites now planned.

"We have a rather rosy view of how easy it is to restore tidal marshes based on small projects next to high sediment sources with no wind waves, like Carl's Marsh," says Williams. Carl's Marsh is a 45-acre site with a starting elevation of near mean lower low water that was breached in 1994 by Fish & Game's Carl Wilcox dynamiting the levee.

"Initial elevation is a key determinant, but also the bigger sites take longer, and a lot of sites proposed these days are larger than anything done in the past," says Orr, referring to three projects of the thousand-acre-scale now in the works for the North Bay (Cullinan, Montezuma and Hamilton). "I'm not saying we shouldn't do large-

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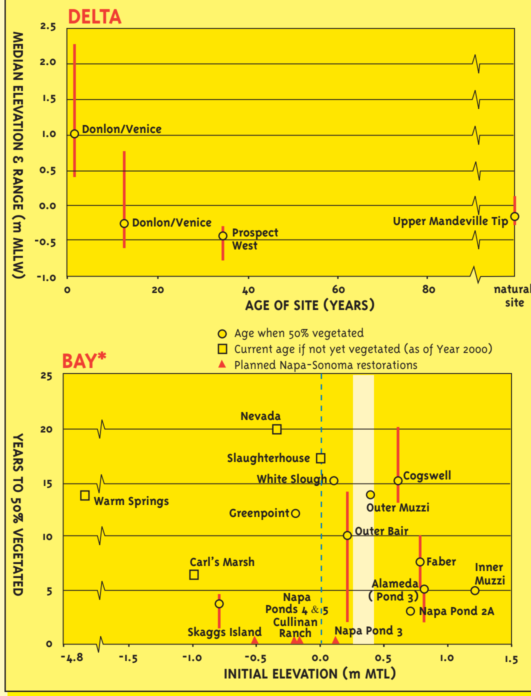
BAY-DELTA VEGETATION THRESHOLDS



Rate of vegetative colonization as a function of initial elevation. Shaded bar represents the approximate Spartina foliosa *colonization elevation. Error bars represent the range of uncertainty. *Subsequent lateral colonization occurs down to approximately mean tide level (MTL).*

Source: Williams & Orr

scale restoration, just that we should have different expectations," she says.

The review of the 15 sites also suggests that the formation of tidal channels within the marshes is greatly dependent on whether and how high the site is filled prior to breaching. Filled sites at marsh-plain elevations (above 0.3 below mean higher high water) can vegetate quickly, but after several decades show little development of tidal channels.

Tidal channels are good habitat for fish, perhaps some of the best shallow water habitat there is. Looking at three artificially filled sites (Faber, Pond 3 and Muzzi), Williams and Orr found that they had been filled too high to allow tidal channels to develop quickly.

Fyke net at low tide in Petaluma Marsh

"If you fill all the way up to the natural marshplain level, then the only time you get appreciable water on the plain is during the spring tides — just a few times per year," says Williams. "That's not enough water draining on and off the marsh daily to scour out a tidal channel. " Williams recommends a fill threshold of about 1 foot below MHHW to promote channel development. "It used to be that success was defined by vegetation, but we now realize channels are important for fish and detritus moving in and out."

The message that both BREACH studies, and the related research, seem to be hammering home is that the key to success is the restoration of processes, not just landscapes. "Natural evolution of marsh processes is going to take time, far longer than anyone thought," says Williams. "Our highest priority should now be to develop restoration strategies and objectives that are compatible with long-term estuarine processes."

RESEARCH

Where's the Food?

The shallows grow food, providing places where the warmth, light and slow-moving conditions in the water spur the growth of tiny drifting plants and animals (plankton) at the base of the estuarine food web. Just what kind of shallows produce food, and under what conditions is a key science question for CALFED as it sets goals and buys land for the creation of new shallows to sustain smelt, salmon and other native fish on the wane. A recent CALFED-funded investigation into the food question — overseen by the U.S. Geological Survey and conducted by a multidisciplinary team including scientists from the Survey, three universities and the Department of Water Resources — suggests that the best food isn't coming from where we thought it was, that the supply is limited and that the Delta's ability to produce food, in general, is not only low, but in decline.

"You have to figure out what's limiting living resources before you can conceive of programs to restore them," says team leader Jim Cloern of the Geological Survey.

Food in the estuarine ecosystem derives from organic matter — nutrients, broken-up bits of plants, algae and phytoplankton (the plant form of plankton) in the water and soil. And one key task for the research team was to assess the sources and quality of organic matter (measured as dissolved and particulate organic carbon, or DOC and POC, in science acronymese) in the Delta. Organic carbon is the source of the energy and calories that fuel biological production at the base of the food web. To trace the carbon in Delta waters back to its sources, Cloern's team used stable isotopes, biomarkers and mass-balance models.

"If you're trying to find out where the food comes from, you need as many different clues from as many different sources as possible," says Cloern. "There's no one tool, marker or method that can tell us if a particle of organic matter is 2000-year-old stuff from the soils around Red

The Geological Survey's Andy Arnsberg on the lookout.

Bluff, or phytoplankton produced in the reservoir behind Shasta Dam or nutrients coming out of the Sacramento sewage outfall."

Cloern's team found that one biogeochemical tool (stable isotopes of carbon and nitrogen) commonly used to identify sources of organic carbon in other estuaries doesn't work in the Delta. "We analyzed an unprecedented 868 plant samples for C-N isotope ratios and could find no unique signatures for individual plant groups," he says. Instead, the particulate organic matter in the Delta often has isotopic compositions that "don't look like any living plant sources," says Cloern, suggesting that the bulk of it might be very old and low-quality matter originally produced by terrestrial plants.

Most of the organic matter in the Delta, according to mass-balance models constructed by Alan Jassby of U.C. Davis, is imported by its rivers, or what scientists call outside (or "exogenous") sources. But most of what's delivered is what Cloern calls "trash organic carbon." This low-quality dissolved organic matter has to be converted into living particles (a process facilitated by bacteria) before it can be consumed by clams, copepods and other critters at the next level of the food web, a conversion resulting in an inefficient respiratory loss of a large fraction of its energy. Even though the pool sizes of POC are smaller than those of DOC in the Delta, the former is more biologically available and energy efficient as a food pathway because the POC is the pool containing phytoplankton cells. As Cloern likes to say, "Phytoplankton rules."

While some phytoplankton comes from rivers, most is home grown in the Delta's shallows and marshes. "The bottom line is that three years ago, we thought outside sources were the biggest contributors to Delta food supply, but now we know that inside sources are most important," says Cloern.

So just how productive are the Delta's shallows? The Survey's Brian Cole incubated phytoplankton in Delta water samples to come up with a general idea of how fast these tiny plants grew. He plugged his findings into a model, which projected growth rates, and gave the rates to Jassby. Jassby then examined data on chlorophyll a and turbidity levels in the Delta between 1975 and 1995, which were collected by the Interagency Ecological Program (chlorophyll a and turbidity are two excellent indicators of productivity, the former as a measure of phytoplankton abundance, the latter as a measure of light penetration for photosynthesis).

By combining the IEP data with the phytoplankton model, Jassby calculated that the inherent rate of the production in the Delta is, and has been for decades, low. "It really surprised us that it was such a small number," says Cloern (70 grams of carbon per square meter per year, a rate of primary production half that of poor producer Lake Tahoe and smaller than the most nutrient-depleted regions of the ocean). In addition, Jassby and Cloern projected that between 1975 and 1995, the Delta's productivity rate declined by 43%.

Why is the Delta's phytoplankton productivity so low? Partly because of the natural turbidity of Delta waters due to high suspended sediment concentrations and partly because the system has been so altered by dams, diversions and mining — producing deeper rivers and fewer shallows and floodplains, which in turn has limited light penetration and increased cloudiness in the water. In addition, an invasive clam called *Corbicula fluminea* has been very likely eating the phytoplankton (if the eating habits of its fellow invader, *Potamocorbula*, down in the North Bay is any indication). Cloern says restoration planners have to accept, as a result, that the Delta is an "inherently low production system," and work to enhance production — the opposite, he says, of efforts in Chesapeake Bay, for example, where phytoplankton blooms from excessive nutrients are a nuisance.

Not having very much phytoplankton may be limiting the zooplankton that feeds on it, according to another related study. Anke Mueller-Solger, of U.C. Davis, fed juvenile *Daphnia magna* (a water flea common among zooplankton) detritus-rich waters collected seasonally from four different Delta habitats to examine the relative nutritional value of phytoplankton compared to the much more abundant particulate detritus. Nutritional matter in the samples ranged from 330 to 3800 parts per billion of POC, with about 15% of the carbon contributed by phytoplankton and the remainder by detritus particles.

Growth rates of the water fleas measured in the lab differed between samples from different habitats: the fleas grew faster in samples from shallower habitats (largely a function of how much phytoplankton was available to the water fleas in these samples). Mueller-Solger's results suggest that even in a system like the Delta, with high amounts of potentially nourishing detrital carbon, zooplankton may still require the nutrition associated with fresh phytoplankton. "These water fleas need to eat their veggies, and enough of them," says Mueller-Solger.

Cloern's team applied her lab conclusions about how much chlorophyll a zooplankton need to thrive to their work out in the field. In over 200 samples collected in different seasons and regions of the Delta, they found that 83% didn't have enough chlorophyll a to support zooplankton growth, such as that measured for the water fleas. "So there is less algae in the water than they need to grow at the optimal rate," says Cloern. "And there's more and more evidence that food is limited at several different trophic levels. In terms of restoration, we may now need to accept that it's a property of our system that organisms that rely on phytoplankton as a food resource can't get enough of it to grow well. "

Or they may not be getting the right kind. Mueller-Solger points out that not all algae are created equal, and generating the right amounts of the right kinds "so that everybody finds their favorite food may be rather challenging as a restoration goal."

So how do the conditions in two existing Delta shallow water habitats affect these food web relationships? Another member of the U.S. Geological Survey team, Lisa Lucas, directed a close-up comparison of Mildred Island and Franks Tract in the Central Delta to find out. "They look the same from the sky, but they're functioning completely differently," says Cloern.

Franks Tract is a 3,000-acre island first flooded in 1938, and nearby 1,000-acre Mildred Island was flooded in 1983. Though Franks Tract was a lot less subsided than Mildred when first flooded, neither have developed much marsh cover and both contain large stretches of open water. But the main difference, from Lucas' point of view, is that Mildred appears to be a net producer (or "source") of phytoplankton for the pelagic food web

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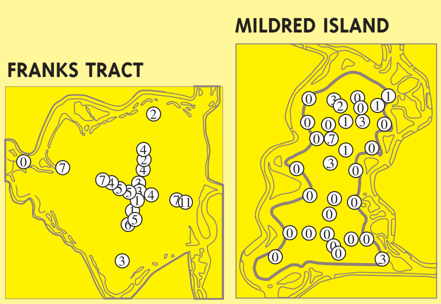
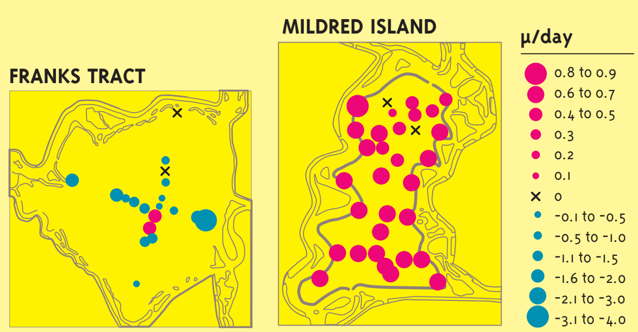
GRAZING AND GROWTH COMPARISON



Corbicula grazing rates in meters per day calculated from measured clam size, density and biomass in June 1999. Franks Tract was "carpeted" with clams (mean grazing rate of 4.4 m/d), while Mildred had far fewer clams (mean grazing rate of 0.4 m/d).



Here researchers combined light-temperature-dependent photosynthesis, respiration and Corbicula grazing to calculate "μ", or the rate of phytoplankton growth available to zooplankton. If μ is positive, then that location is a local net source of phytoplankton (quality food) to the zooplankton; if μ is negative, then that location is a net sink.

Source: Jan Thompson & Lisa Lucas

Where's the Food?

(e.g., zooplankton), while Franks appears to be a net importer (or "sink"),based on June 1999 field sampling (see below).

In addition, hydrodynamic modelling by Survey postdoc Nancy Monsen suggests that Franks is more "leaky" while Mildred is more "lakey. "Both have levee breaches and tides sloshing in and out, but Franks has a lot more breaches and a lot more sloshing, says Lucas. In such a leaky system, particles have multiple opportunities to come in one opening and perhaps go out another, she says. With all the sloshing around in Franks Tract, residence times for water and particles were low, whereas residence times in the southern part of Mildred Island were quite high, offering a good incubator spot for phytoplankton.

One major reason for the source-versus-sink difference between the two tracts is the heavy grazing going on by the invasive clam *Corbicula*. According to the Geological Survey's Jan Thompson, Franks Tract is chock full of *Corbicula*, with benthic grazing rates averaging about four cubic meters per square meter per day, whereas Mildred had relatively few clams and low grazing rates averaging one tenth of that seen in Franks. "Right now we don't have a clue why *Corbicula* is paving the bottom of Franks but absent from some regions of Mildred," says Cloern.

"Franks is both leaky and carpeted with clams, a virtual 'Roach Motel', so it ends up being a huge local sink for phytoplankton, perhaps even a regional sink affecting the food supply in the environment around it," says Lucas. "With so many clams, you'd imagine Franks would have zero chlorophyll a, but we actually found low nonzero levels, which suggests it's importing biomass. "This means that, in order to understand shallow water habitats like flooded islands, restoration scientists have to understand the peripheral connected channels as well, because tidal currents drive rapid exchanges between shallow and deep habitats. "We can't study shallow open habitats as isolated habitats because they're not isolated — they are strongly connected to surrounding waters," says Lucas.

To get at this connection, Monsen illustrated patterns for particle transport in and out of the two islands and deeper channels around them, using a tidal hydrodynamics model called Delta-TRIM (see next page).

Hydrodynamic-biological modelling now in progress will further test the producer/importer hypothesis. New studies underway in 2001 indicate that many of the Mildred/Franks findings from 1999 are holding up in other seasons and other years. In September 2001, Geological Survey scientists launched a new field experiment aimed at quantifying phytoplankton fluxes at the opening in Mildred's northeast corner. "This new information will help us assess whether Mildred is pumping substantial amounts of phytoplankton out to adjacent environments versus 'hoarding' it locally," says Lucas.

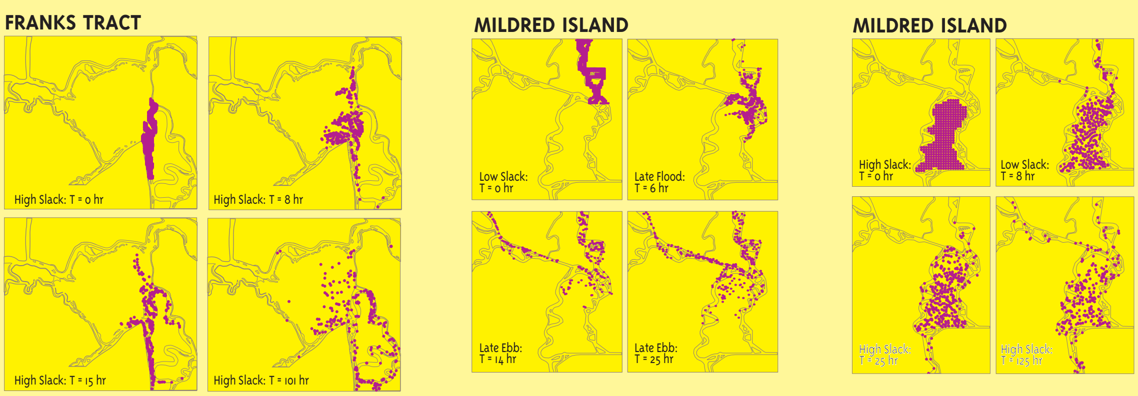
Zooplankton sampling

So what all these investigations suggest, in sum, is that while shallow water systems may look similar on the surface, they can function completely differently, and have high variability in the biomass of phytoplankton, and thus high variability in their potential to support fish and pelagic food webs. "There's no such thing as a generic shallow water habitat that's good for food and Delta smelt," says Cloern.

In terms of restoration outcomes, some aspects are controllable — like the nature and number of the breach sites, and some are not — like the *Corbicula*. Clearly, the population ecology of *Corbicula*, as a factor affecting food supplies in restored shallows, needs to be better understood. Scientists also want to explore how physical features like levee breaks, island depths, tides and freshwater flows, as well as the nature of exchanges between the shallows and the depths, influence food production.

"We need to learn more about what these systems turn out to be before we go out and make more of them," says Lucas.

PARTICLE TRACKS AND TIDAL SLOSHING



Computer model-generated particle movements in Franks Tract. Tides cause particles to slosh in from adjacent channels and back out again. After several tidal cycles (t=101 hr), numerous particles have been imported to Franks Tract. Many levee breaks around Franks Tract allow for further interaction between the shallow lake and nearby deep channels, rendering Franks Tract very "leaky."

Channel-lake sloshing also occurs at Mildred Island. After several tidal cycles, numerous particles have been imported to the island. Because there are fewer levee breaks at Mildred than at Franks, this lake-channel interaction is less extensive.

Initially, particles are uniformly distributed inside Mildred Island, but tides cause Mildred to lose particles to adjacent channels. After several tidal cycles (T=125 hr), many more particles are retained in southern Mildred than in northern Mildred, suggesting a longer "residence time" in the south than in the north.

Source: Nancy Monsen

HYDRODYNAMICS

A RIVER RUNS THROUGH IT

The "shallows" conjure up visions of wide waters placid enough for food to grow and fish to swim whichever way they please. But two Department of Water Resources engineers (Enright and Guivetchi) knew that something different was going on in Sherman Lake when numerically modeled salinities throughout the western Delta were extraordinarily sensitive to how they handled the lake in their models. At their urging, the U.S. Geological Survey's Rick Oltmann and Jon Burau put drifters and current and salinity meters in Sherman Lake in the fall of 1998. Instead of the expected quiescent conditions, with long water residence times and associated phytoplankton production, he found "a major conveyance pathway" between the Sacramento and San Joaquin rivers through the lake.

Burau found that the tide arrives about an hour earlier on the Sacramento side of Sherman Lake, mainly because the tide wave moves faster on the Sacramento River because it is deeper, and has to travel farther on the San Joaquin River before it reaches the lake. These geometric factors produce "a big water-level difference across Sherman Lake, which in turn creates strong, fast-moving tidal currents and large net exchanges across the island," he says. The stronger currents are limited to the east side of Sherman Lake, while the west side exhibits the expected quieter conditions.

Burau found similar rapid tidal exchanges going on in the northern part of Mildred Island, but not in the southern part. "We can't assume that the shallows are homogeneous," he says. "We're finding a wide diversity of hydrodynamic conditions and habitats within large islands."

Other research by Burau and colleagues downstream shows similar rapid tidal exchanges between Honker, Grizzly and Suisun bays and their surrounding shallows. Exchanges in certain areas are like "one big mixmaster," says Burau. "If you were a little fish, unless you could swim like crazy, you wouldn't hang out there."

In Grizzly and Honker bays, the exchange occurs across a very wide area, whereas in the Delta, exchanges are highly constrained, moving through narrow breaches. "When you're deciding what flavor of shallow water habitat you want, the width, depth and location of the breach is very important," says Burau. (To view drifter paths, see Burau p.12).

APPLICATION

Take-Home Messages

Our recent scientific scrutiny of the shallows suggests a number of new things for resource managers, policymakers, activists and the public to think about in terms of managing and restoring the Bay-Delta ecosystem. Clearly, we've learned that many of the restoration plans we originally developed based on biological priorities – saving this fish or this mouse from extinction, bringing back the tules or the cordgrass – now need to be rethought based on geomorphic possibilities. The existing landscape and the way water now moves across it limit our ability to build new habitats. We've also clarified some of our more complex restoration goals – not just wide shallows but also edges and margins, not just more vegetation but whole ecosystem processes, not just endangered species but many native species, maybe even a few non-natives, not just one type but a mosaic of habitats...

"All this new information confirms that we have to be more mindful of processes," says the California Resources Agency's Tim Ramirez. Or as the Geological Survey's Lisa Lucas puts it, we need a detailed study of processes (as opposed to mere quantification of outcomes, such as the amount of vegetation or a head count of endangered fish) to see the underlying mechanisms that create within-habitat and between-habitat differences in ecosystem function.

"The rationale for creating freshwater tidal marshes has not gone away, it's now a question of where it's easiest and best to do it," says Philip Williams.

The meager sediment supply won't be easy to overcome for restoration managers. Clearly, really deep islands are not the ones to breach if you want to make marshes or native fish habitat any time soon. In a sediment-starved system, managers may now need to decide which new sediment sinks – gravel beds on creeks, floodplains along rivers, Delta islands or old salt ponds – are the most important ones to fill first. Or which ones will come out the way we want them to based on the best available science.

"Every last fisheries project on our creeks and rivers upstream can affect the sediment budget downstream," says Stuart Siegel of Wetlands and Water Resources. "More importantly, by creating new sediment sinks via restoration throughout the Estuary, along with new fill projects like SFO's runways, we will fundamentally alter how sediment moves through the system and the places where it erodes and deposits."

Williams thinks we need to start focusing on less subsided areas around the periphery of the Estuary like McCormick Tract, places where it may be more "practical" to achieve marshplain levels. Since sediment demand could become so high relative to its supply, resource managers should consider phasing restoration over time, particularly if large new areas like the South Bay salt ponds (a 100-million-cubic-yard sediment sink) are restored. "We have to create sediment sinks slowly, maybe a few a year, rather than opening up all the ponds at once," Siegel says. As sediment gets scarcer, accretion of organic matter through vegetation decomposition may also become an increasingly important component.

Even if some flooded Delta islands don't make good marshes, they may make good food, another management consideration in an ecosystem that's not only short on sediment, but also on phytoplankton. Mildred Island offers an interesting case in point – too subsided to get much sediment accumulation but producing a good crop of phytoplankton in its quieter corners. Indeed Mildred's depth and lack of vegetation are pluses, in terms of producing little of that lethal byproduct of restored wetlands – methyl mercury. "It doesn't make any sense to restore the food supply if it's just moving more toxic elements into the food web," says the Geological Survey's Jim Cloern.

The mercury side of the restoration equation seems to stymie scientists and restoration managers alike. The Yolo Bypass and Cosumnes floodplain restorations, for example, are great for food, native fish, and sediment inputs to nearby restoration sites, but could turn out to be bad for mercury, because they have some of the biggest inputs of mining mercury from upstream. "We really need to get a handle on mercury methylation levels in these two floodplains, and factor our results into any habitat expansion there," says U.C. Davis' Darell Slotton.

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Take-Home Messages

Another theme emerging for management is to get over the old "control freak" syndrome and find ways to build in variability. The scientists say that "extreme events" are good for native fish and plants and bad for invaders, and that the permanent nature of the subtidal areas created by flooding Delta islands probably facilitates invasions. "In a lot of cases, it's the disturbances — storms, floods, droughts — that formed the system, so trying to control them is the worst we can do," says the University of Washington's Charles Simenstad. "It's actually counter to ecosystem complexity."

Denise Reed of the University of New Orleans agrees, saying, for example, that 1998 flood conditions really helped the ecosystem. "Restoration planners need to be prepared to capitalize on flood events, to allow rivers to overflow banks into flood plains and deliver sediment pulses where they're needed," she says.

Salinity is also an important factor in creating the variability that puts a damper on invasions, says Water Resources' Curt Schmutte. If we let the tides into vast new areas of the Delta, salinity may change across the Delta, he says, and could, in turn, affect what kind of species live in the shallows.

It does seem to be clear that non-native fish are thriving in the Delta, and the flooding of large islands may be giving them a fin up. The Department of Water Resources' Lenny Grimaldo thinks it may be time to ask ourselves if the focus on recovery of endangered fish through restoration is even feasible. "We keep promising we're going to recover native fish, but it may be time to revisit our original idea of desired restoration outcomes and acknowledge other restoration benefits such as more striped bass for the sport fishery or the simple aesthetic pleasure of waters and wetlands," he says.

Despite the obstacles and complexities, Cloern and other scientists think we should persevere with shallow water habitat restoration. "It's still worth it if our expectation is to prevent endemic species from going extinct in our lifetime. I think we can create pockets of Delta smelt habitat, maybe just 10,000 acres. But we're not going to turn the Delta back into a 300,000-acre tule marsh," he says.

"Personally, I'd rather see an area wet than urbanized, regardless of the non-natives," throws in Grimaldo.

Questions remain. What should CALFED spend its money on first, and should it continue investing heavily in shallow water habitat projects, or is the better bet seasonal floodplains like the Yolo Bypass or San Pablo baylands that are not so heavily subsided as the Delta islands? According to Simenstad, the science suggests that restoration may be faster and more feasible the lower (e.g., outside the Delta) the place is in the system. In some places many small patches of certain kinds of habitat may have to suffice. In others, larger tracts may be possible.

Given the within-Delta problems, CALFED should think more about preserving the meager, relict wetlands that are left, says Simenstad. "The Port of Stockton has proposed Browns Island for dredging and dredge material disposal. Is that appropriate when it may take decades, if not a century, to restore anything comparable in the Delta?" he asks.

CALFED may also want to think about whether its early ecosystem restoration vision of making the Central Delta a better place for fish by creating a wide, long habitat corridor between the Mokelumne River and Suisun Bay still has merit, says the CALFED Science Program's Kim Taylor. This vision directed early ideas of where restoration should take place, but some scientists are still scratching their heads over its basis. "As far as I can tell this is a concept borrowed from terrestrial conservation ecology, where there has been debate about the value of corridors connecting patches of habitat, but how it would work for fishes of open-water habitats, I don't know," says S.F. State's Wim Kimmerer. "Although Delta habitat corridors could be a great idea, it has not been supported by any science I know of. We need to see the underlying conceptual model with supporting data before we do any restoration based on the corridor idea." The recent years of shallow water research certainly provide some relevant data and may even suggest the need to reconsider the corridor-based underpinnings of CALFED planning.

Another concept that needs to be revisited is the connectivity between the watersheds, the Delta and the Bay. "One major assumption I personally think we need to throw out is that shallow water habitats are totally disconnected from the 'body' of San Francisco Bay," says Simenstad, pointing out that these habitats are connected not only by tidal waters but also by major estuarine interactions, and fish and avifauna population dynamics.

In any case, this young science of restoration has discovered a lot in the past few years, fueled by CALFED's investment in it, which some scientists say has had the added benefit of moving many academics and graduate students into Bay-Delta specific research.

The feedback on restoration produced by this research is certainly welcomed by CALFED management. Before the 2000 Record of Decision, the CALFED mission was to get stuff done, says Ramirez. "People wanted to see things happen, and we went ahead and did a lot of restoration projects with Prop. 204 and Category III money, but not as much science and research. Now, with Sam Luoma on board, the science is coming in. All these things we've learned should become part of our criteria for deciding which projects to fund in the future, and will help us become more strategic in our investments."

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This special publication was paid for by the CALFED Science Program. Special thanks to Ecological Applications *(re: Lucas, Cloern, Thompson & Monsen),* Restoration Ecology *(re:Grimaldo, Orr and Williams) and* Limnology & Oceanography *(re: Mueller-Solger) for letting us preview some of the data to appear in forthcoming articles. For more info on sources and citations, please contact the authors above or see the* IEP Newsletter.

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