Human Management and Development of the Sacramento-San Joaquin Delta: A Historical Perspective

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The history of the Sacramento-San Joaquin delta system should be understood as a series of incremental habitat alterations commencing with Native American management practices and concluding with the operations of the flood control, water export, and other modern cultural changes. Although Native American management was probably benign from an ecosystem perspective, most alterations since 1833 have been detrimental to populations of anadromous fish. The restoration of marshlands and riparian forest may help to reverse this trend.

The Prehistoric Delta

The geomorphic configuration of the Sacramento-San Joaquin Delta reflects the structure of the Great Central Valley Geosyncline. It is unique among deltas in that it is confined within the Coast Ranges with its outlet through the narrow Carquinez Strait. The delta is generally on flat terrain at sea level. The hydrology was dominated by tidal currents, which created an intricate dendritic network of sloughs and channels. Because of the confinement of the delta, its waters were fresh during much of the year. The gradient of the Sacramento River below Sacramento was less than a foot per mile. As they approached the delta, the Sacramento and San Joaquin rivers braided into multiple distributory channels (Figure 1). These narrow channels served to regulate inflows of fresh water. Floodwaters resulting from winter storms would back up, flooding the vast plain of the Sacramento Valley and forming an inland sea, which would slowly discharge to the delta.

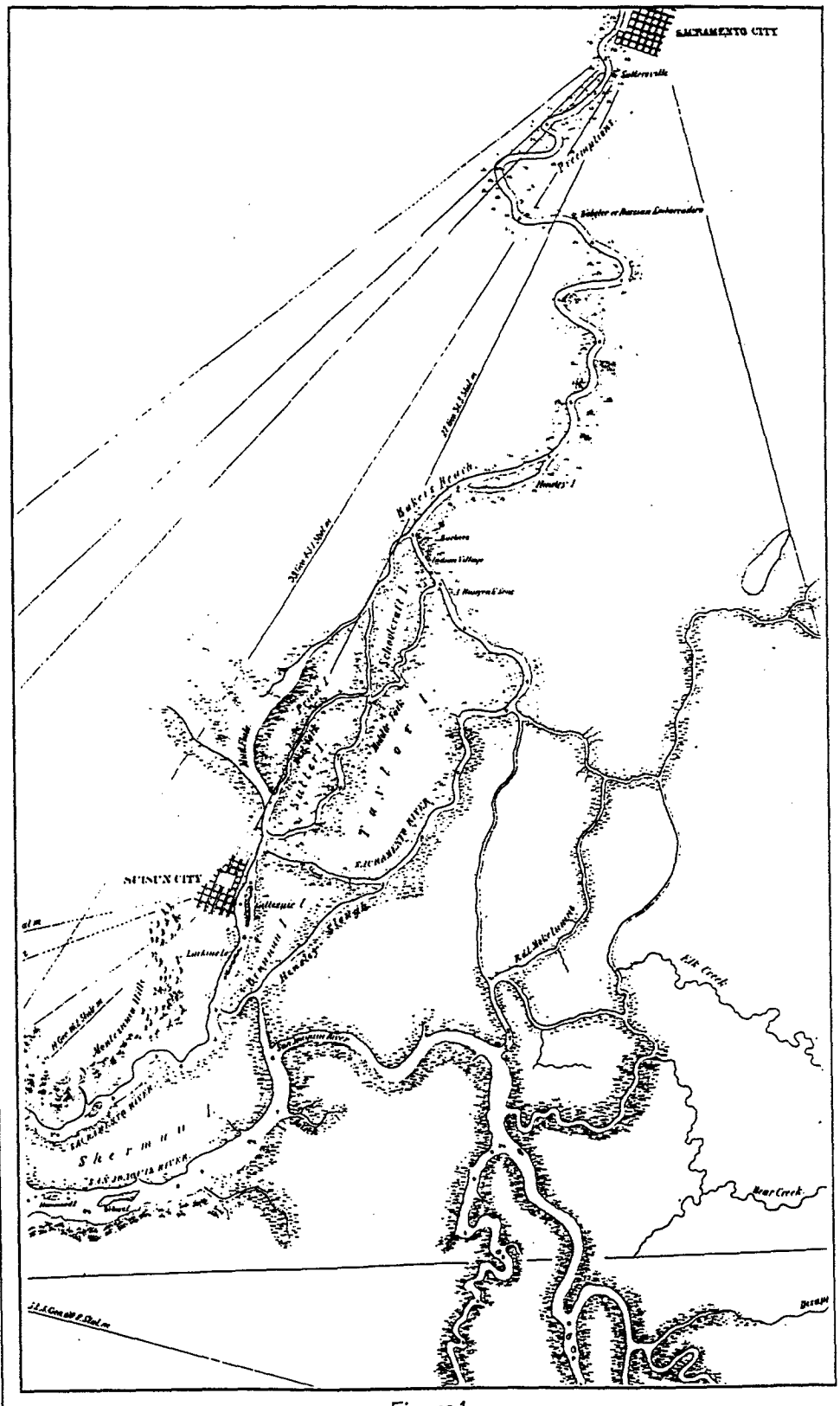

Figure 1
The Sacramento and San Joaquin Rivers,
from an 1850 Map by Cadwalader Ringgold, Commander, U.S. Navy

The central and southern delta were predominately extensive marshlands, under water at high tide. Dominant vegetation was tules, *Scirpus: lacustris, tatora, acutus Muhl.* ex *Bigel* and *californicus.* The common reed *Phragmites australis* was also present. These bulrushes provided the basic substrate for a complex food web that supported a rich aquatic habitat. In addition, as they died and decayed, the tules provided sedimentary input to a layer of peat soil from which they grew. The aquatic habitat supported a large and varied population of fish, waterfowl, and terrestrial animals. Of particular note were four populations of salmon: fall, late-fall, winter, and spring runs. It is hypothesized that the marshlands provided a critically important transitional stage in the life history of outmigrant juvenile salmon, particularly the late-fall and spring runs. The network of sloughs provided rearing and refuge habitat for fry that otherwise would be swept by the frequent floods triggered by heavy seasonal rains into salt water and the sea before they were physiologically ready. Also noteworthy was an abundance of beavers, for which the delta was ideal habitat, as they did not have to construct dams in the sloughs to flood their lodges, and the riparian forests provided abundant feed. Early explorers (Wilkes) reported the presence of grizzly bears, which presumably preyed on the abundant salmon. Early delta travelers also commented on the swarms of mosquitoes, which made travel in the delta almost unbearable.

The northern delta, along the channels of the Sacramento River, which was the largest source of fresh water and sediment to the delta, was characterized by wide (400-600 feet) natural levees, behind which were some marshlands and also parklike oak meadow lands. Sacramento River banks, steep and as much as 10 feet high, supported a dense riparian forest of oak and sycamore. Some of the trees towered above the masts of sailing ships that used to go up to Sacramento (Figure 2). The forest shade cooling the river water and the contribution of woody debris to the river also provided important components to the migration habitat of young salmon.

Native Americans

Native Americans were present in the delta for about 10,000 years. Ethnographic studies (Krober *et al*) suggest that the delta may have been the cultural and language group boundary between the Youkut people of the San Joaquin Valley and the Wintun and Maidu of the Sacramento Valley. Delta inhabitants, living on the high ground of the natural levees and on constructed mounds, can be understood as an assemblage of small independent tribes, speaking related languages and making their living in similar ways. However, for reasons set forth in this paper, not a great deal is known about what may have been a rich and unique culture. A few tantalizing facts remain in anecdotal reports from early European travelers and explorers.

It is reported (Dr. John Marsh 1841) that delta inhabitants constructed conical houses using tule reeds. The first mapper of the delta in 1775, Don José Canizares, was impressed with the graceful lines and speed of the natives' bundled tule-reed canoes, which Canizares called *balsas.* The use of the term is significant. It suggests that at least one of his party at some time had been in Peru, where to this day bundled reed canoes called balsas are constructed by the Uros people of Lake Titicaca, who live in the marshlands and construct conical reed huts. One other reed-based culture is known to have survived into recent times: the Marsh Arabs of the Tigris-Euphrates delta, who also built houses and boats from reeds.

The marsh people of the delta were known to fish with nets, spears, and hook and line. The rancheria of Pescadero, at the confluence of the San Joaquin and Old rivers, was visited in 1849 by Bayard Taylor, who reported, "The salmon exceeded in fatness any freshwater fish I ever saw. They were between two and three feet in length, with a layer of pure fat, a quarter of an inch over the ribs." As with most other tribes in northern California, the primary source of food was the oak acorn, which was ground into meal (Wilkes).

Delta natives actively managed the ecosystem of both the marshes and the oak meadow lands by periodic burning. This practice probably kept

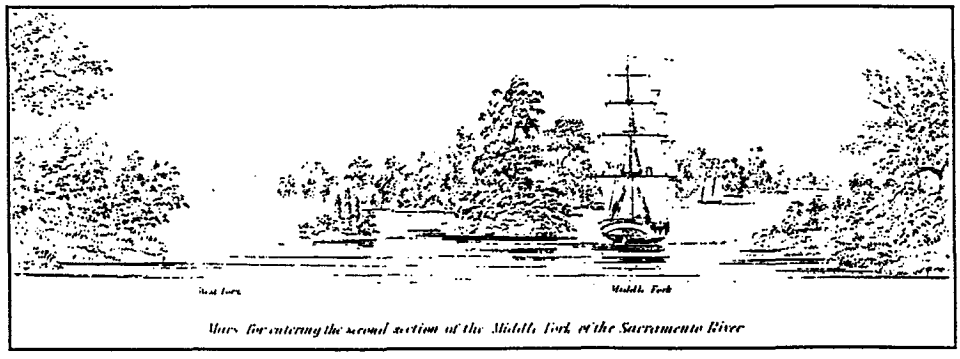

Figure 2
The Sacramento River at Middle Fork,
from an 1850 Map by Cadwalader Ringgold, Commander, U.S. Navy

the riparian forest clear of underbrush, facilitated acorn harvest, and improved fresh crops of tules, much as the present practice of rice field burning does. Native American occupation of the delta may be seen as an example of ecosystem management, which modified it by burning in order to harvest surplus production of biological resources.

Spanish Colonization

The first European colonization of California by the last expansion of the Spanish Empire in the late eighteenth century had little impact on the delta. Other than periodic explorations and military raids searching for runaway mission inmates, the Spanish and Mexican colonists avoided the delta.

The Beaver Hunt

Starting with the peripatetic Jedidiah Smith, who arrived in California after an epic transcontinental journey in 1827, the beavers in the delta were systematically trapped for their fur, an industrial product of that era. After two successive beaver harvests, Smith packed his furs to the Hudson's Bay Company post at Fort Vancouver on the Columbia River. The Chief Factor at Fort Vancouver, Dr. John McLoughlin, reacted to this unexpected delivery of furs from a new source by mounting a Hudson's Bay trapping expedition to the delta. Beginning in 1829, annual parties of French-Canadian trappers were sent south over the Siskiyou Mountain passes, usually led by the colorful Michel Laframboise, who established his base at what is still known as French Camp. By the beginning of the gold rush in 1848, the beaver population had been effectively removed. While they may not have been a keystone species, their extirpation undoubtedly began the alteration of the delta ecosystem.

The Demise of the Tribes

The beaver trappers may have brought something with them to the delta. In 1833 a virulent epidemic of malaria, carried by the ever present swarms of mosquitoes, swept through the Native American population, which lacked antibodies for this new pathogen. The result was mass death. An American trapper, George Yount, reported that "the bodies of untold thousands lay withering on the plains and fertile valleys .... Deserted and desolated villages stood tenantless all over the valley." A later smallpox outbreak carried away the few survivors of the great malaria epidemic. This event destroyed what may have been a unique delta culture before there was an opportunity to study it. The epidemic can be considered an ecosystem alteration, as it effectively ended the periodic tule burning by the tribes.

Riparian Deforestation

Starting with John Sutter's establishment of a settlement at the confluence of the Sacramento and American rivers and the subsequent discovery of gold , regular ship commerce began on the Sacramento River (Figure 2). Sailing ships quickly gave way to steamboats, which could ascend the river more reliably. The riparian forest of sycamore and oak provided a convenient source of fuel for the steamboat boilers. By 1850, 28 steamers were calling at Sacramento. Until the turn of the century, the river was the primary route of commerce, and the steamboats were the carriers. Firewood was felled, cut, and stacked on the levees for sale in Sacramento and San Francisco. The loss of shade canopy and woody debris contribution to the river was probably a major impact on aquatic habitat for salmon and other fish.

Hydraulic Gold Mining

Once the easily accessible placer gold deposits in the beds of rivers tributary to the Sacramento and San Joaquin were exhausted, the prospectors turned their attention to the slopes above the river canyons. It was discovered that ancient gold-bearing riverbeds adjacent to the canyons were overlain by thick layers of unconsolidated conglomerate sediments. Tunneling to reach the ancient placer deposits was dangerous and chancy of success. A new technique quickly evolved. High in the watersheds, mountain streams were diverted into flumes that ran along the ridges, then down through iron pipes to the mines, where the water at high pressure was used to wash away the sediment overstory. The sediments were washed down the rivers to the delta, where the fine silts deposited, rapidly shallowing the channels and sloughs. The combined results of water diversion, sedimentation, and river channel alteration had a devastating effect on salmon populations.

In addition, the massive load of fine sediments shallowed and restricted the water delivery capacity of the Sacramento River, exacerbating its tendency to back up floodwaters into the Sacramento Valley. A major flood in 1862 converted the valley to an inland sea. A series of floods followed, bringing torrents of sediment onto the valley floor. Bitter political and legal battles over the hydraulic mining issue between a coalition of farmers and fishermen against the miners went on for two decades. Finally in 1880, in what was the Nation's first environmental action, the courts ruled against the miners. The mining ended. Today many mountain creeks are still choked with debris left from the mining (Alan Harthorn).

Levee Construction and Land Reclamation

After the Native American depopulation and with the onset of the gold rush, pioneer farmers began to settle along the Sacramento River, planting crops to meet the high demand for vegetables and grain from the mining industry and its support economy. Settlers soon discovered the consequences of winter flooding. The natural levees would be overtopped during a flood; the water would pour into side sloughs and rise behind the levees. Beginning on Merrit Island in 1850, low "shoestring" levees were constructed along the Sacramento River to prevent overtopping of the natural levees. The mouths of side soughs leading to marshlands behind the natural levees were diked and closed to prevent flooding from behind.

As landowners raised levees to protect their property, floodwaters would tend to flow over unleveed land downstream, creating incentive for more levee building. The important role played by women in the levee construction process should be noted. The life of a delta farmer was hard, and illness was common. Many pioneer landowners died young, leaving their widows in possession of the land. The widow Kercheval was responsible for the complete reclamation of Grand Island, one of the first to be enclosed.

The process of enclosing and draining marshlands was accelerated by the passage of the Reclamation Act of 1902, which granted public wetlands to individuals who drained and converted them to agricultural use. It was given further impetus by state legislation by the visionary Will S. Green of Colusa, which created reclamation districts that could assess landowners and act collectively to levee and enclose a district. Although gradual, the reclamation process was constant and profitable. In 1878, 30,000 acres had been reclaimed. By 1910, with 323,000 acres reclaimed, the delta had become the market garden of California. The demand for ever higher and wider levees resulted in new technologies. The clamshell dredger and the bulldozer originated in the delta. Reclamation peaked in the 1940s at 490,000 acres, leaving remnant patches of tules on the channel islands in the southern delta. Outmigrant salmon no longer would find refugia in the side sloughs. The vast expanses of marshlands were gone, replaced by polderized farmlands, which began to subside as their peat topsoil oxidized and blew away.

Flood Control Projects

As levee construction was taking place in the delta, it was also advancing upstream on the Sacramento River. Protecting the growing capitol city of Sacramento from the devastating floods of the late nineteenth century became a major political issue. Debates raged for decades in the halls of the Capitol, as the floods recurred, over whether the Sacramento River could be confined within its banks by separate action to raise levees by the reclamation districts or whether some grand, centrally planned project was necessary (Davis). All parties to the debate agreed on one element; the Sacramento River channel restriction above Rio Vista must be removed. Shallowing caused by mining debris was impeding steamboat navigation as well. Congress authorized the U.S. Army Corps of Engineers to channelize the river. A bend at Decker Island was cut off. Steamboat Slough and the main stem of the river were dredged and deepened. The dredge spoil was used to build up the levees. The effect of channelization was to remove the flow control function performed by the distributories near Rio Vista. Flood water would move quickly to salt water, carrying outmigrant salmon seaward, perhaps before they had reached the transitional stage of smoltification.

Of all the delta islands, only Ryerson Island has never been flooded since the islands were enclosed and drained. As the islands have subsided, the risk of flooding has increased. One island, Franks Tract, has become permanently flooded. It has become mandatory to constantly raise the height of the levees. With some islands, such as Sherman, as much as 20 feet below sea level, constant vigilance in levee maintenance has become the order of the day. This has included keeping them devegetated and armored with riprap, which degrades their riparian aquatic habitat value.

Water Development

Delta and Central Valley farmers came to an early understanding that crops would have to be irrigated. The dry summer climate would allow nothing to grow that was not watered, other than a spring grain crop. For delta farmers, the answer was relatively simple, the fresh water in channels and sloughs between the islands could be pumped or, if the island was below water level, siphoned over the levee into distribution ditches. Tailwater was pumped back into the sloughs. Today there are about 1,800 water diversions in the delta (Dan Odenweller, DFG). Almost none are fitted with fish screens to prevent entrainment of juvenile salmon.

On the Sacramento River, a similar process of localized riparian water diversion took place. As landowners not located by the river needed more water, pumping plants proliferated

the river. Will Green had an power. He founded Glenn-Colusa Irrigation District, the first large-scale water project on the Sacramento, and carried legislation to authorize large-scale irrigation districts. The resulting headworks and delivery canal could take up to a third of the summer flow of the Sacramento River. The irrigation district continues to work on a successful fish screen.

A similar water development process occurred south of the delta. La Grange Dam, on the Tuolumne River was built in the 1890s. It was the first high dam, diverting water to the Turlock and Modesto Irrigation Districts at a site in the Sierra foothills. Spring-run chinook salmon, which ascend high into the mountains in the spring to hold for the summer and spawn in the fall, could no longer pass up the river.

All the tributaries and finally the mainstem of the San Joaquin River (Friant Dam in 1944) were blocked by mainstem high dams. The San Joaquin spring-run salmon once feasted on by Native Americans at Pescadero and later by Italian fishermen of Collinsville had been extirpated.

Exotic Species

Striped bass, an Atlantic Coast anadromous species, were transported to the delta by railroad in the 1870s to improve recreational fishing. They established themselves and to a certain degree took up the ecological niche occupied by salmon and green sturgeon. Salmon populations continued strong, and the "stripers" became a popular species to fish for in the delta.

Water hyacinth, an aquatic floating plant that forms dense mats, was accidentally introduced into California. It impedes boat traffic and in some instances may actually block upstream migration of salmon.

Asian clams, saltwater filter-feeders, were introduced from merchant ships discharging ballast water into San Francisco Bay. The clams have spread upstream as far as Chipps Island and have densely populated the bottom of San Pablo and Suisun bays. Because Asian clams feed at the lowest trophic level on algae and phytoplankton, they may be having a serious impact on the food chain of the bays adjacent to the delta. As freshwater aquatic habitats have been greatly reduced by reclamation, the saltwater bays may have become a more significant habitat for juvenile salmon. The issue needs further study.

Toxins

Placer mining in California was followed by hard-rock mining, which exploited the mineralized deposits typically found where a spreading center and its associated submarine hot springs have been accreted onto a continental margin by subduction. Gold, silver, copper and heavy metal complexes were mined extensively in the Sierra Nevada and in the mountains at the headwaters of the Sacramento River. As the mines were worked out and abandoned, some of them began to discharge acid leachates carrying dissolved heavy metals. Iron Mountain Mine, near Redding, is the primary contributor of toxic metals to the Sacramento River and delta ecosystem. At high levels of solution, the water becomes toxic for fish. Action is underway to control and treat this problem at its source.

Agricultural Drainwater

As irrigation water is applied to the land, some of it leaches into the ground or runs off. If fertilizer, herbicides, or pesticides are applied to improve crops, those chemicals dissolve and enter the ecosystem in the tailwater. As farming intensified in the delta, increasing amounts of phosphates, dormant orchard sprays, and herbicide compounds were pumped into the channels. In addition, agriculture in the Sacramento and San Joaquin basins contributes a large component of potential toxins to the delta. It is difficult to quantify or estimate the ecological effects on aquatic systems, but a range of sublethal effects are known. Many resident fish in the delta are not safe for human consumption.

The California Department of Boating and Waterways is spraying large quantities of an industrial herbicide, 2-4-D, directly into delta waters to eradicate water hyacinth. To the author's knowledge, effects of the Water Hyacinth Control Program on the delta aquatic ecosystem have not been studied.

Recreational Boating

With the post-World War II economic boom in California came a huge increase in recreational boating. Parked trailer boats are common in the suburbs. With its intricate maze of channels and smooth water, the delta was an ideal playground for boaters. Where a few yachtsman had gunkholed, marinas were built along the levees where there was road access. Today there are over 75 marinas in the delta. The ecological effects of intensive power boating have been reported (Nils Stolpe). They include hydrocarbon pollution from outboard motors, bottom effects caused by propellers in shallow water, and damage to shoreline habitats caused by wakes. It is possible to observe a larger quantity of tule habitat near speed control signs today (Dick Daniels).

Water Export

It is beyond the scope of this paper to tell the story of the federal Central Valley Project and the State Water Project. The ecological impacts of hydrologic changes brought about by using delta channels to transfer water southward across the delta for export to the San Joaquin Valley and Southern California have been extensively studied, reported on, and fought over. Suffice it to say that water export is held to be the most significant impact on salmon in the delta by many fishery conservation biologists. This problem is being addressed through the ongoing delta planning process.

Conclusions

Clearly, the lost world of the marshlands cannot be restored as it once was. But it may be possible to restore important elements of the ecosystem structure and function. Those areas that have retained their original habitat characteristics, such as the meadows along Snodgrass Slough, should be protected from further development. Some islands that have not subsided too deeply to be viable wetlands could be opened to tidal flows and restored as freshwater marshlands. In other areas, new levees could be constructed with a wide setback behind the old levee, which could be allowed to grow a riparian forest. The area between the new and old levee could be a recreated marsh, with openings through the old levee that would provide refugia for fish. A wide range of habitat restoration strategies are being considered in the CAL-FED delta planning process. In the author's opinion, these proposed habit restoration measures will restore fish if they are implemented in the context of a fish-friendly hydrologic regime. If they are built as mitigation for high levels of water export from the delta, they will fail. A balanced approach that deals with both hydrologic management and habitat restoration is needed to restore California's magnificent salmon resource.

Second Delta Smelt Workshop

It's been 3 years since the first delta smelt workshop brought together scientists doing research on delta smelt and successfully identified specific research goals. Well, what have we learned since then? Did we achieve our research goals? What information do we still need? These questions will be addressed at the second delta smelt workshop, to be held May 16 at Contra Costa Water District headquarters in Concord.

The workshop will concentrate on delta smelt life history, with emphasis on certain life stages — larval, juvenile, adult, prespawning adult. To keep the workshop to one day, we have limited talks to our current understanding of delta smelt biology and what questions still need to be answered. A future workshop may concentrate on management objectives (*eg*, recovery objectives, habitat requirements/restoration, mitigation requirements).

For more information, contact Dale Sweetnam (209/942-6112, dsweetna@delta.dfg.ca.gov) or Leo Winternitz (916/227-7548, lwintern@eso.water.ca.gov).

Agenda
DELTA SMELT WORKSHOP
May 16, 1996
Contra Costa Water District Headquarters, 1131 Concord Avenue, Concord, California

0800	Welcome/Introduction	Dale Sweetnam/Leo Winternitz
0815	Delta Smelt Life History Cycle	Chuck Hanson
0845	Current Sampling: Studies and Biases	Dale Sweetnam/Geir Aasen
	Basic Delta Smelt Biology	
0915	Delta Smelt Diets	Jenni Lott/Matt Nobriega
0945	Reproduction and Gametogenesis	Randy Mager
10:15	Break	
1030	Genetics	Bernie May
1130	Environmental Tolerances/Physiology	Joe Cech/Tina Swanson
1200	Lunch	
	Applied Topics	
1245	X2 Relationship/Silversides	Bruce Herbold
1315	Entrainment/Culture	Ted Sommers/Joan Lindberg
1345	Toxins	Jana Hofius
1400	Delta Smelt Recovery	Peter Moyle
1430	Break	
1445	Panel Discussion: Delta Smelt Life History: What have we learned, what do we need to learn?	Moderator, Peter Moyle
1630	Future Directions	TBA