GONE WITH THE FLOW

HOW THE ALTERATION OF FRESHWATER FLOWS
IS KILLING THE BAY-DELTA ECOSYSTEM

The Bay Institute

The Bay Institute is a nonprofit research, education and advocacy organization dedicated to protecting, restoring and inspiring conservation of San Francisco Bay and its watershed, from the Sierra to the sea.

Since 1981, The Bay Institute's policy and scientific experts have worked to secure stronger protections for endangered species and habitats; improve water quality; reform how California manages its water resources; and promote comprehensive ecological restoration for San Francisco Bay, the Sacramento-San Joaquin Delta, and the estuary's tributary rivers, streams, and watersheds.

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EXECUTIVE SUMMARY

***Gone with the Flow* tells the story of how fresh water, flowing from the mountains through the river systems of California's Central Valley into the Delta and San Francisco Bay, creates and sustains the unique ecosystems of this vast estuary and its watershed. The report also explains how the increasing diversion of water by humans over the last few decades has drastically reduced the amount of flow to the estuary and changed natural runoff patterns, devastating the Bay-Delta ecosystem and its fish and wildlife populations. Many species are now on the brink of extinction.**

Mountain streams once provided cold, fast-flowing water for salmon, steelhead and other migratory fish, but dams on almost every river system have blocked the natural flows and forced spawning fish to use less suitable habitat downstream. *Removing or modifying barriers to flow and fish passage would expand available habitat for these migrating fish and improve stream flow conditions above and below the dams.*

High flows during winter and spring in **lowland rivers** once spread into floodplains and sustained riparian forests, creating a corridor of rich, highly productive habitat for young fish as they migrated to the sea – but over the last half century these seasonal high flows have been shifted to less ecologically important periods in the Sacramento River system and have been virtually eliminated on the San Joaquin system. *Restoring higher flows for several months in winter and spring would inundate floodplains again and ensure successful migration for salmon and other fish species.*

The estuary's unique inland **Delta** is the junction point for all the flow from the many rivers and streams of the watershed, as well as for many species that move into the Delta to migrate or spawn at some point in their life histories. Over time it has become a lethal junction, losing more than a third of its average natural inflow to upstream diversions and losing hundreds of millions of aquatic organisms each year to extreme reverse (upstream) flows caused by pumping at giant federal and state water project facilities in the south Delta. *Maintaining positive (downstream) flows in the winter and spring is essential to reversing the trend to extinction. Positive flows are particularly important in drier years and when population levels of species at risk of extinction are low.*

High flows entering the upper reaches of salty **San Francisco Bay** during winter and spring create a vast expanse of extremely productive and unique brackish water habitat, and the abundance of many aquatic creatures has always closely tracked the amount of this freshwater inflow. The reduction of freshwater inflow to the Bay by over half in recent years has eliminated much of the habitat, and populations of flow-dependent species have collapsed as a result. *Ensuring that about 75% of the natural runoff in the watershed reaches the Bay during the ecologically important winter-spring period would restore this habitat and provide conditions for recovery of these collapsing populations.*

Despite the evidence, some people claim that freshwater flow is not important compared to other factors affecting the Bay-Delta ecosystem, and that actions to fix these other problems would be more effective than restoring flows. *Gone with the Flow explains that:*

- The scientific case for the importance of **flow** – and the damaging effects of altering flows – is strong, whereas there is little evidence that any of these other factors are causing the recent catastrophic declines of fish and wildlife.

- The loss of **wetlands** and other habitats (cited by some as an alternative cause) occurred decades before the current fish and wildlife declines; whereas those declines track closely the more recent reduction of freshwater flow volumes in the estuary.

- Water quality has mostly improved in recent decades – a notable exception being where reduced flows concentrate pollutants.

- Populations of introduced **predators** like striped bass, blamed for eating native fish, co-existed for a century with the natives and have declined along with them. In contrast, predators that have been introduced more recently (e.g. sunfish and bass) actively benefit from the unnatural flow patterns imposed on the estuary.

- Native fish and wildlife populations, and the Bay-Delta environmental conditions that support them, have steadily declined over time, while the **ocean conditions** some would point to as an alternative cause have varied significantly over the same period and actually improved in recent years.

Gone with the Flow also reveals that there is more than enough water to restore flows to the Bay-Delta ecosystem and still meet California's water supply needs if:

- All Californians contribute their **fair share** of water to restoring flows and conserving water supplies, spreading the responsibility among many parties. Currently, many water users have no obligation or incentive to restore flows or to conserve. The agricultural sector, which uses most of the state's developed water supply, pays less for water and invests less in conservation than other sectors.

- Californians receive more benefit from each unit of water delivered – by using it more efficiently through **conservation**, by using it more than once through **recycling** and **reclamation**, and by storing more of it in **groundwater aquifers** during wet years.

- California's water supply system is managed for a warming 21st century climate – by replacing energy-intensive imported water with **regional self-sufficiency** using local water savings, by **measuring** water use and its energy cost, and by using **flood and groundwater basins** to naturally capture, store and clean water for later use.

THE SAN FRANCISCO BAY-DELTA ESTUARY: A FRESHWATER RIVER RUNS THROUGH IT

The immense and majestic ecosystem of San Francisco Bay and the Sacramento – San Joaquin Delta is a unique national treasure. This Bay-Delta estuary—the largest on the west coast of the Americas—is one of the most recognizable and beloved natural features in California. The Bay-Delta is home to hundreds of plant and animal species, many found nowhere else in the world; nursery habitat and migratory highway for the state's most important fisheries and waterfowl populations; and an economic, cultural, and recreational resource for millions of people.

The San Francisco Bay-Delta is the largest estuary on the west coast of the Americas. | *Courtesy of the Atlas of Panoramic Images*

But the Bay-Delta is much more than what we see when we cross over its waters on a bridge or stroll along its shores. The San Francisco Bay-Delta estuary is the culmination of a vast watershed that extends nearly a thousand miles, from beyond the Oregon border in the north, to the Tehachapi Range in the south and to the crest of the Sierra Nevada in the east. The linkage between the Bay and its watershed, which covers more than 40% of the state, is made by hundreds of rivers, large and small, that rise from their individual headwaters to ultimately join the estuary. The junction point for this river network is the Sacramento – San Joaquin Delta, the gateway to San Francisco Bay. And the indispensible element that connects and flows through the whole of the system is water.

No other resource comes close to the importance of water for California's environment and quality of life. Flowing through our rivers, streams and estuaries, it creates dynamic and vibrant ecosystems that provide vital habitat for a wide range of organisms, including fish, birds, shrimp and crabs. In turn, these organisms support valuable tourism, recreation and fishing industries. Fresh water also irrigates farms that supply large proportions of the nation's food, and is used by industry for manufacturing, power generation and cooling. And every one of California's 37 million citizens expects and depends on safe, clean water for drinking and household uses.

Fresh water is a finite resource, but we treat it as if it is not. Nearly two-thirds of California's water supply comes from the state's rivers and streams, fed by seasonal rainfall, snowmelt and perennial springs. Over the past century, we have built a massive and complex system —thousands of dams, many thousands of miles of levees, giant aqueducts and powerful pumping facilities—to capture, control and divert that water. This infrastructure and the way we manage it has left our rivers among the most altered and threatened landscapes in the state, their life-giving flows disrupted and depleted, and many of the ecosystems and valuable resources they support in severe decline. There is overwhelming evidence that California has been living beyond its water means:

- Freshwater flows into the Bay are reduced by more than 50% in half of all years.
- Some of the estuary's tributaries that used to flow year-round are dry for all or part of the year.
- Populations of many aquatic species have collapsed in the last decade.
- The state's 150 year-old salmon fishery has been closed or severely restricted in recent years.
- Many of the state's rivers and streams are impaired by low flows and the pollution problems that accompany low flow conditions.
- Unrealistic water supply commitments create demands that cannot be met, creating a never-ending cycle of over-allocation of water resources.

Gone with the Flow seeks to illustrate in simple terms the critical role freshwater flows play in the Bay-Delta system, and how altering the natural rates and timing of flows is undermining the productivity of the ecosystem and the sustainability of the many services it provides to the people of California. The report concludes by describing some of the ways that California can restore freshwater flows to the Bay-Delta ecosystem while continuing to meet the state's water supply needs into the future.

Sources that document the report's findings and provide further information are listed in the References section.

The Watershed Of The San Francisco Bay-Delta Estuary

The water that feeds the Bay-Delta Estuary once flowed from 40% of the state. Today it normally drains the Sacramento and San Joaquin River basins, which cover about 30% of the state.

FRESHWATER FLOW VS. "OTHER STRESSORS"

THE DEBATE THAT'S NOT

Some people claim that factors other than flow alteration are entirely to blame for the decline of the Bay-Delta ecosystem. According to them, ammonia pollution, predation by introduced species, loss of historical wetlands, poor ocean conditions, or something else is responsible for the collapse of fish and wildlife populations, and, until these "other stressors" are addressed, increasing freshwater flows is a waste of resources. Clearly, there are many factors contributing to the estuary's decline, and these factors should be addressed to the extent and in the priority that solid science documents the problem. Currently, there is strong scientific evidence that alterations to natural freshwater flow amounts and timing are the most critical source of the problem and that these flow alterations exacerbate other problems in the Bay-Delta system, such as pollution. In contrast, there is little evidence that other factors are the primary cause of the long-term declines in ecosystem productivity, and need to be fixed first. Simply put, fixing our broken aquatic habitats is not an "either/or" proposition; restored freshwater flows are integral to saving the Bay-Delta ecosystem from collapse, and should be followed by other actions to restore lost habitats and improve water quality.

FRESHWATER FLOW: THE INDISPENSABLE ELEMENT

The Sacramento River, the Bay's largest tributary, is home to more kinds of Chinook salmon than any other river on earth, including fall-run Chinook that support California's commercial salmon fishery. The river also supports more than 50 other fish species, including two species of sturgeon, steelhead, rainbow trout, splittail, Sacramento pikeminnow, striped bass and American shad. | *Photo courtesy of Diana Jacobs, Sacramento River Preservation Trust*

WATCHING THE RIVERS FLOW

In the Bay-Delta ecosystem, flowing water is the indispensable element that creates the environmental conditions and habitats that support thousands of different species, including plants, fish, birds, mammals, reptiles, amphibians, insects, shrimp, crabs and clams. These creatures range in size from microscopic plankton to nine-foot long sturgeon and the massive trees that shade riverbanks. Indeed, flowing water is the habitat for many of these species. It provides a continuous migration corridor for fish like salmon that must use both freshwater and ocean habitats during their lives, helps transport young fish, nutrients and sediment downstream to the estuary and ocean, and inundates floodplains that provide habitat, nutrients and food. Where it mixes with salt water in the Bay, a unique brackish water habitat is created that is essential for commercially important marine and migratory species like Dungeness crab, herring, halibut, flounder, and salmon, as well as less visible estuary residents like delta smelt. The productivity and diversity of the flora and fauna in each of these habitats reflects the health of the environment that we all share.

DAMMED, DIVERTED & DRIED UP

Dams, levees, pumps and other physical modifications we have made to rivers and the Delta have changed how water flows through the watershed and into the estuary in many ways: how much water, how fast it flows, when it flows, and its quality and temperature. Dams block fish migration corridors and alter seasonal flow conditions in the rivers downstream; levees straightjacket rivers and prevent

Until 2010, the Bay's second largest tributary river, the San Joaquin, was dry for nearly sixty miles because of excessive water diversions, which eliminated the largest spring-run Chinook salmon run in California. A settlement to restore the river and its fishery resulted in the interim rewatering of the river in 2010 and requires salmon to be reintroduced in 2013 and flows to be released year-round starting in 2014. | *Photo courtesy of Revive the San Joaquin River*

them from seasonally flooding the rich floodplain habitat on the other side of the river bank; and water diversions reduce flows and remove fish, plankton and nutrients from the ecosystem along with the water being diverted. Reduced freshwater flows into the Bay shift the important habitat formed at the mixing zone between fresh and salt water upstream out of the Bay and into the lower river channels in the Delta. These changes have eliminated some habitats, degraded those that remain and, from the perspective of the ecosystem, created a permanent state of drought that did not exist in nature. Native fish and wildlife species are well adapted to survive periods of drought, but when our water management turns naturally wet years into dry ones and dry ones into critical drought conditions, the ecosystem is constantly under stress, with no opportunity to recover. Today, six different fishes that rely on the Bay-Delta ecosystem—two of the four runs of Chinook salmon, steelhead, green sturgeon, delta smelt and longfin smelt—are at risk of extinction, and populations of many other organisms are declining, a strong indication that flows are no longer adequate to maintain healthy rivers, a healthy estuary, or healthy fisheries.

WATER QUALITY VS. WATER QUANTITY

Is poor water quality in the Bay-Delta system an alternative explanation for the decline in ecosystem productivity, rather than flow alteration? Some regions of the estuary experience periodically high levels of ammonium (a byproduct of natural processes and wastewater treatment plants) or locally high concentrations of pesticides running off agricultural fields. Some groups have suggested that these, or perhaps new pollutants (such as those found in human health care products), have caused the widespread, long-term fish and wildlife declines. The fact is that any foreign chemicals in our water are a source of concern, and there is too little information about the toxicity of many chemicals used in this country to be complacent about their effects. As a guiding principle, therefore, we should eliminate or reduce the introduction of known or potential contaminants to all environments.

But there is a big difference between the common sense policy of pollution prevention and the claim – largely unsupported by scientific evidence - that our water has recently become too polluted to support fish and wildlife. Indeed, thanks to federal and state regulation, in most areas our water is cleaner today than it was just a few decades ago. What has also changed, unfortunately, is a reduction in the flows that once helped to dilute and flush natural and introduced compounds out of our fragile fresh water systems. As freshwater flow rates declined, the estuary became more and more vulnerable to the effects of pollutants entering and persisting in the aquatic environment – and will remain so until we restore more natural flow amounts and patterns.

MOUNTAIN STREAMS

COLDWATER PARADISE IN THE MOUNTAINS

Most of the large rivers in the Bay-Delta watershed begin high in the mountains, born of perennial springs and runoff from rain and snowmelt. The clean, cold, fast-flowing water found here makes these mountain streams ideal habitat for abundant runs of salmon and steelhead, which need reliable coldwater flows for their eggs and young as well as for the food organisms on which their offspring depend. Mountain streams also serve as essential holding and refuge habitat for coldwater dependent species during the summer and fall, when water temperatures in the foothills and valley floor are too warm for these animals. Winter- and spring-run Chinook salmon, which migrate up the rivers during the cool winter and spring seasons but do not spawn until later in the summer and fall, require coldwater holding habitat in order to survive and become reproductively mature. The journey these fish make to reach these upper river habitats is remarkable, traversing the watershed from the ocean to the mountains, swimming hundreds of miles, climbing thousands of feet, navigating rapids and even ascending small waterfalls, all using flowing water as both highway and guide.

Yuba River above the large foothill dams. There is good habitat for salmon in the upstream reaches, but salmon can't get to it currently because dams block their passage. Fish passage around the dams is being examined and would reopen over 100 miles of upstream salmon habitat.
| Courtesy of Diana Jacobs, SRPT

YOU CAN'T GO HOME AGAIN

Today, almost every single one of the Bay-Delta's tributary rivers has been dammed to create large storage or hydropower reservoirs in the foothills and mountains. In addition to blocking the flow of water and sediment downstream, these large dams, which are impassable for salmon, steelhead and other migratory fishes, have effectively eliminated much of their spawning and holding habitat. Steelhead, for instance, cannot access 85% of their historical spawning habitats as a result of impassable dams. Unable to migrate upstream to their historical habitats, these fish are forced to spawn in the river below the dam where the river bottom habitats they use for building nests may be unsuitable because of reduced flows and high water temperatures. Some species have been able to survive in the lower rivers, others have not. For example, spring-run Chinook salmon were wiped out in the San Joaquin Valley after dams were built on all the major tributary rivers. Fall-run Chinook have been able to hang on in small numbers by using all of the remnant spawning habitat below the dams, although their numbers are declining.

All but one of the ten largest rivers in the Bay-Delta watershed are dammed to create huge storage reservoirs, blocking flows from all of their tributary mountain streams.

In the few mountain streams that remain accessible to migratory fish (as well those that support isolated resident fish populations), flows have been reduced by both on-stream water diversions for water supply and hydroelectric power and groundwater pumping at nearby wells. On-stream water diversions are also a hazard for resident and migrating fishes because very few of them are equipped with fish screens, which prevent fish and other small aquatic organisms from being removed from the stream along with the water.

CAN YOU RESTORE WETLANDS WITHOUT WATER?

Historical Connected Waterways of the Central Valley

The Transformed Watershed

Mapping the change: Over one thousand miles of upland river are no longer available as salmon habitat because of the barriers imposed by dams; additional lowland river mileage is lost to salmon because of the dewatering of the San Joaquin River. Nearly 5,000 square miles of lowland floodplain and estuarine intertidal habitat, including 900 square miles of historical lake, has also been lost. Restoration of natural processes and rehabilitation of degraded habitats can bring some of this habitat back into the aquatic system.

Is habitat loss the real cause of declining fish and wildlife populations? After all, less than 5% of the estuary's historical wetlands, 11% of its vernal pools, and about 6% of its riparian zone remain, in a quilt of disconnected patches mostly too small to sustain dependent species. This habitat loss has been one of the most important long-term changes to the Bay-Delta, and restoring these habitats is a key ingredient of any recipe for improving the health of the estuary. But reversing habitat loss won't cure all that ails the Bay-Delta. The fact is that most wetlands, floodplains, riparian zones, and other habitats were converted to agricultural or urban landscapes in the 19th and early 20th centuries. While these changes certainly devastated the ecosystem at the time, many fish and wildlife species survived and rebounded, only to decline rapidly in the late 20th century, when the amount of water diverted from the estuary began to increase dramatically. In the final analysis, all of these aquatic habitats are just that: aquatic. They require sufficient flows to function properly. We need both land and water to make an aquatic habitat that works.

LOWLAND RIVERS

CREATING THE RHYTHM OF THE WATERSHED

As they travel through the foothills ringing the Central Valley to the valley floor, lowland rivers accumulate the collective flows of many tributary streams. Flowing throughout the year, even during droughts, these rivers provide the seasonal rhythm of the watershed: variable winter flows punctuated by occasional peak flows following a rainstorm, a long period of high flow as the mountain snowpack melts during the spring, and then a slow attenuation to steady low flows during the later summer and fall. The life patterns of nearly all of the native plant and animal species that live in or migrate through the Bay-Delta ecosystem are tied to this sequence.

Rivers are essential corridors for migratory fish like salmon, steelhead, sturgeon, Sacramento splittail, shad, striped bass and others that must travel between the ocean and freshwater habitats to complete their lifecycle. These species rely on both the volume and direction of flow to trigger and orient their migrations—upstream for spawning adults and downstream for young fish migrating to the ocean.

Young migrating fish may spend many months in the river, growing and developing in preparation for the entering the estuary and ocean; these fish require acceptable fresh water flows year-round. Forests and seasonal wetlands adjacent to the river can provide abundant food for these fish as well as for a diversity of other aquatic and terrestrial animals – access to this food is improved when the rivers run high and inundate riparian and side-channel habitats. The amount of habitat is related to the amount of flow: in general, the more flow, the more habitat. This is particularly true in areas where, during periods of high flow, the river can spill over its banks and spread out onto a floodplain, an extremely productive habitat. Studies have shown that young salmon that migrate downstream through a floodplain have higher survival and grow faster than fish that migrate down the narrower, less productive and often channelized river channel. One endemic fish species, the Sacramento splittail, is a floodplain specialist that relies on inundated floodplains for most of its spawning habitat – in years when floodplain habitats are not accessible, very little spawning occurs. In addition to providing important habitat, the water from floodplains carries nutrients, sediment and food with it as it flows back into the river or estuary, extending the ecologically beneficial effects of floodplain inundation well downstream. High flows also stir up and transport sediment, making river waters more turbid (or cloudy) and protecting young fishes from being eaten by predatory fish and birds that use sight to catch their prey.

Young salmon that migrate downstream through a floodplain (right) rather than in the river channel (left) have higher growth and survival rates. | *Photo courtesy of Jeff Opperman*

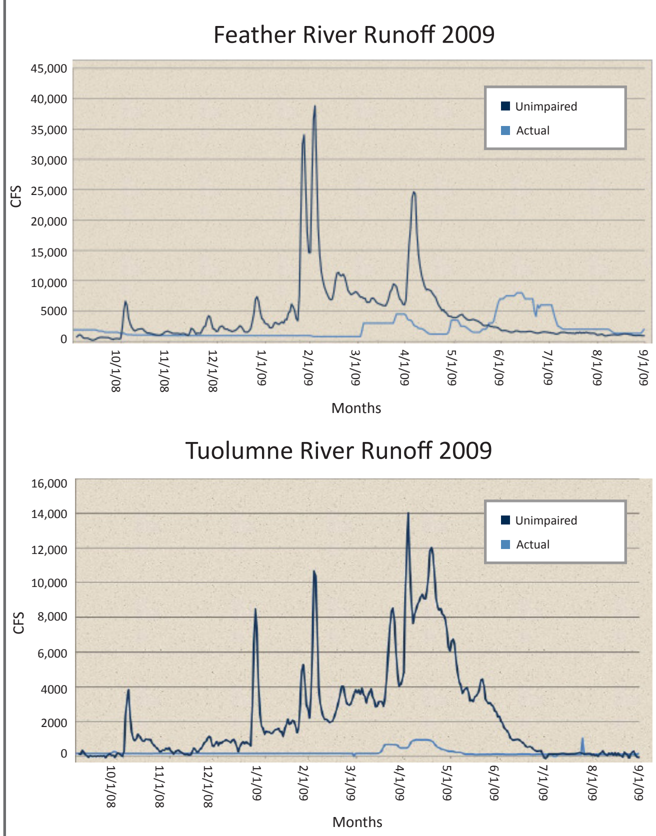
HIGH, DRY & BENT OUT OF SHAPE

Dams have drastically changed river flow and sediment regimes throughout the Bay-Delta watershed. Most of the dams are operated to capture and store spring snowmelt flows, reducing river flows during this critical season and dampening or eliminating important biological cues for migration and reproduction for most of the animals that inhabit the river. Low river flows prevent spawning gravels and other habitats from being replenished, reduce the amount of rearing and spawning habitat in the river and, as the weather warms, allow water temperatures to rise, often to levels that kill salmon and steelhead. Indeed, the principal reason winter- and spring-run Chinook salmon and steelhead are now on the brink of extinction is because flow and environmental conditions in the rivers below dams, which block the fish from their historical mountain stream habitat, are intolerable. Below the dams, many irrigation districts divert water directly from the rivers, exacerbating the problem of reduced flow as well as drawing fish into diversion structures. The extent and frequency of floodplain habitat has also been severely reduced, a consequence of both low spring flows resulting from dam and diversion operations and the levees that confine the river within a narrow channel.

In the Bay-Delta watershed, flows have been most drastically reduced in rivers in the San Joaquin Basin. For each of the four major rivers there, the Stanislaus, Tuolumne, Merced and San Joaquin, much of the water captured in the reservoirs is diverted at the dams and in the majority of the years, flows in the rivers below the dams are very low and the high winter flood and springtime snow melt flows have been virtually eliminated. Until recently, all of the flow in the San Joaquin River was diverted, leaving the river dry in long stretches. During the irrigation season, a significant portion of the water that does flow in the lower San Joaquin river is polluted runoff from farms and cities. These low flows and pollution are the main reason that Chinook salmon in San Joaquin Basin rivers have declined from hundreds of thousands of fish to just a few hundred: studies show that young salmon migrating from these rivers are more successful when river flows are high than when flows low. Based on results of these studies, in seven of the past ten years, not enough water made it down the San Joaquin to ensure successful salmon production.

Springtime flows in the San Joaquin Valley are reduced by more than 90% in most years, in effect "flatlining" the rivers in the basin.

In contrast, most of the large dams in the Sacramento Basin are operated to provide water for export from the Delta. Because the rivers are essentially used as canals to convey the water to the export pumps, flows can be relatively high at some times during the year. However, because most water released from the dams is exported from the Delta during the summer and fall, rather than the spring, the timing of these higher flows is too late to provide beneficial migration and rearing habitat for young salmon and other native fishes. In fact, these artificial high flows can be harmful to the river ecosystem by drowning young riparian vegetation established during the spring.



Seasonal flows in the Feather River (top) and Tuolumne River (bottom) show the effects of dam operations that capture and store spring snowmelt runoff. In the Feather River, much of captured spring flow is released during the following summer and fall to transfer the water to the Delta for export to the San Joaquin Valley and southern California. In the Tuolumne River, the captured flow is either diverted to irrigate local agricultural fields, or conveyed across the valley to San Francisco.

THE DELTA

WHERE THE RIVERS GATHER

In the estuary's unique inland Delta, formed by the confluence of the Sacramento, Mokelumne, Calaveras and San Joaquin Rivers more than 60 miles upstream from the Golden Gate, flow from the watershed slows down as the rivers split into a maze of branching channels, dead-end sloughs and dense marshes. When Delta inflows are high following winter storms and during the spring snowmelt period, fresh water flows straight through the Delta and into the Bay, creating a natural transport mechanism that many fish ride from their inland habitat out to the sea. During the rest of the year, while the net flow of fresh water is downstream to the Bay, the tides strongly influence the direction of flow in Delta channels, with water flowing upstream as the tide comes in and downstream towards the Bay as the tide goes out. When Delta inflows are at their lowest, usually in the late summer and fall, salt water from the Bay may intrude into the Delta.

The Delta has little of its original marsh and riparian habitat remaining.

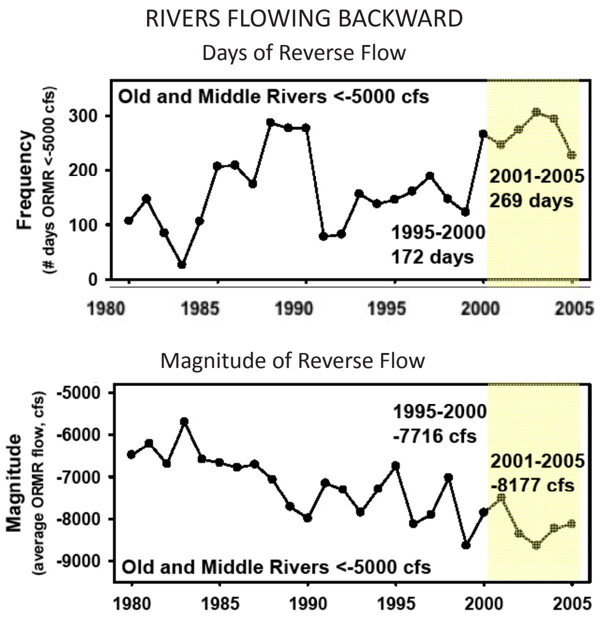
Massive pumping plants in the south Delta draw in water for export. | *Both photos Courtesy of Diana Jacobs, SRPT*

The seasonal variation in inflows and salinity (or "saltiness" of the water) and the daily tidal ebb and flow through the complex network of channels and marshes combine to create a vibrant and productive habitat of fresh or brackish (slightly saline) water that is used by a diversity of fish and wildlife. For resident estuarine fishes, the Delta is the upper reach of the estuary and a number of species, including delta smelt and longfin smelt, depend on it for spawning and early rearing. For migratory species, the Delta is the highway interchange navigated by the fish on their journey between the Bay and its many tributary rivers. Young fishes, including salmon, steelhead, sturgeon, striped bass, and American shad, may spend many weeks in the Delta before entering the Bay and ocean. All of these species depend on characteristics of the water—the amount of flow, its direction and subtle variations in its chemistry—to guide and facilitate their movements in and through the Delta.

In some years, up to 40% of the entire population of the endangered delta smelt may be killed at the Delta water export pumps.

DRAINING THE DELTA'S LIFEBLOOD

Today, the Delta remains the junction point for fresh water flowing from the watershed but its lands and waterways have been drastically engineered for agriculture and water supply. More than 90% of the Delta's tidal marshes have been converted to farmlands by levee construction and draining, transforming the complex Delta landscape into a series of 70 islands surrounded by simplified, narrow, deep channels with many cross-connections but little habitat diversity. The Delta also now serves as the main conveyance, switching station and diversion point for California's largest water projects. In most years, more than a third of the water – already drastically reduced by upstream diversion – that flows into the Delta never reaches the Bay. Much of the water that does enter the Delta, along with with nutrients, millions of small fish, and billions of planktonic plants and animals, is removed by either the massive pumps that export water to the San Joaquin Valley, southern California and the San Francisco Bay Area or by one of the thousands of smaller agricultural diversions



Between 2001 and 2005, high Delta export pumping rates by the State Water Project and federal Central Valley Project caused reverse flows in Delta and lower San Joaquin River channels averaging more than minus 8,000 cubic feet per second for about three-quarters of the year.

distributed throughout the region. Since most of the water entering the Delta comes from the Sacramento River in the north and the pumps are located in the southern Delta, the pull of the pumps has changed the direction of flow in many Delta channels: during much of the year, the net movement of water in central and southern Delta channels and the lower San Joaquin River is reversed, flowing upstream to the pumps rather than downstream to the Bay. As a result, fish that are not killed directly by the pumping may become disoriented or delayed in their migration, exposing them to high predation rates and poor water quality conditions in the interior Delta. Studies have shown that young salmon from the Sacramento River that stray into the central Delta during their downstream migration have a lower chance of successfully making it to the Bay than fish that stay in the main river channel. In contrast, many non-native species that have invaded the Delta find these new conditions quite favorable. Exotic submerged plants now clog Delta channels, providing ambush habitat for non-native predatory fish that also prefer these stable, low flow conditions.

PEOPLE DON'T KILL FISH, FISH KILL FISH?

Some people have suggested that predation – in this case, consumption of native fishes by non-native species like striped bass – is the cause for population declines of the Bay-Delta's threatened salmon and delta smelt. They go on to suggest that predator removal, not flow alteration, is the solution. There is little scientific evidence to support either of these arguments. First, predation is a natural phenomenon in all ecosystems. In the Bay-Delta system, the only places where predation rates may be higher than expected is in some localized areas where the habitat has been degraded by reduced flows and poor water quality, or altered by artificial structures like gravel mining pits and water diversion structures. Second, the species most frequently singled out in these arguments, striped bass, has been present in the Bay-Delta and coexisted with the native fishes for more than a century, including during times when the population abundances of both the natives and striped bass were much higher than today. In fact, striped bass, which have similar ecological requirements to many of the declining native species, have experienced the same long-term and recent catastrophic population declines, falling to record low levels in the 2000s. In contrast to striped bass, predation by warm-water basses and sunfish, species that are native to warm, stable, slow flowing rivers and lakes elsewhere in the United States, appears to be increasing as these fishes become more abundant in the degraded Delta and lowland rivers. Finally, predator removal projects are extremely time- and resource-intensive, they must be maintained in perpetuity and they are rarely successful or effective. In fact, the best approach for reducing the abundance of the non-native predators, as well as other harmful invasives like Brazilian waterweed and the overbite clam that thrive in the Bay-Delta's degraded habitats, is to restore some of the natural flow-driven environmental variability to the ecosystem. Providing higher spring and winter flows and lower summer and fall flows reproduces the conditions under which native species evolved, and would put the most harmful non-native predators at a distinct disadvantage.

SAN FRANCISCO BAY

MORE FRESHWATER = MORE FISH

The brackish water habitat that begins in the Delta reaches its climax in the upper reaches of San Francisco Bay. Here, freshwater outflows from the Delta mingle with saltwater tidal currents in the broad, shallow reaches of Suisun and San Pablo Bays, the large, contiguous blocs of tidal wetlands in the Suisun, Napa and Petaluma Marshes, and the productive areas at the mouths of the Napa and Petaluma Rivers to form a vast expanse of highly productive habitat. Productivity here helps to support the abundance and growth of fish and wildlife found throughout the estuary and its watershed. As freshwater flows increase, more and more of this brackish water habitat is created. Periodic high winter runoff from local Bay watersheds also contributes to creating beneficial habitat.

Just as in the rivers and Delta, seasonal variations in freshwater flow to the Bay create rich and dynamic habitats, provide environmental cues that trigger migration and reproduction, and, through the physical movement and mixing of the water, transport nutrients, sediment and small organisms to and through the Bay. The amount of fresh water flowing into the Bay also determines where ecologically important brackish water habitat is located within the estuary. When freshwater inflows are high, the Bay may be a brackish mixture of salt and fresh waters as far downstream as the lagoon-like waters of the South Bay and out the Golden Gate; when inflows are very low, this mixing zone shifts upstream and enough saltwater may intrude into the Delta to make water there too salty to drink or irrigate crops. Many Bay fish species move around in the estuary based on where water with their preferred salinity is located.

The direct relationship between springtime freshwater flows and the abundance and survival of many Bay species is one of the strongest and best-documented scientific facts about San Francisco Bay.

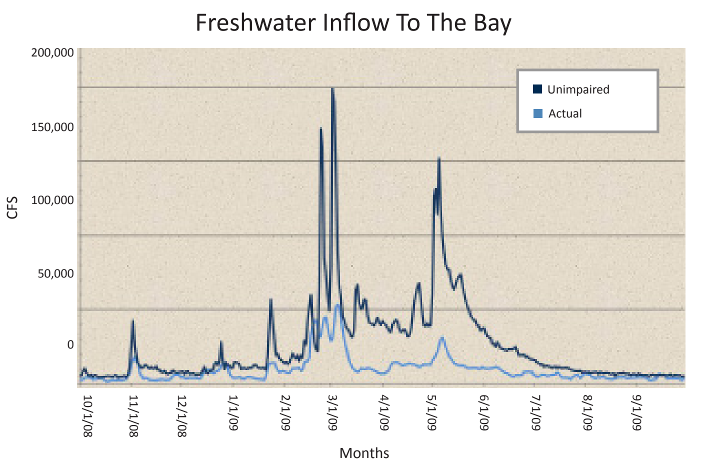
The late winter and spring is a particularly important season for the Bay. Productivity of Bay habitats, as measured by the abundance of native fish and shrimp living there, is directly related to the amount of freshwater flow it receives from its watershed in this period: more fresh water flowing downstream from the Delta results in more fish, shrimp, and other organisms in the Bay. This relationship is exceptionally strong and well-documented. The fact that it holds for a wide range of species, from phytoplankton to shrimp to fish, and has persisted for decades despite species invasions and changes in the Bay's food web, underscores the fundamental ecological importance of seasonal freshwater flows to the estuary.

THE BAY'S MAN-MADE DROUGHT

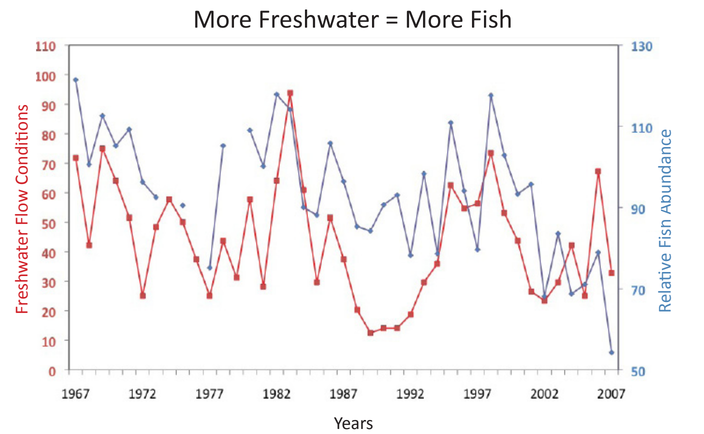
The San Francisco Bay estuary has been dramatically affected by the alteration of flows throughout its watershed. The combined effects of water withdrawals in the Central Valley and water exports from the Delta have reduced annual freshwater inflows into the Bay by more than 50% with increasing frequency in the last several decades. In 2009, barely a third of the watershed's total runoff reached the Bay. Reductions in freshwater flows during the ecologically sensitive spring period have been even greater.

Reducing freshwater inflows has made the Bay a less dynamic and less productive environment: there is less seasonal variation in estuarine habitat conditions; the amount and productivity of brackish water habitat has been reduced; and the location of brackish habitat within the Bay has been shifted upstream, closer to the more hazardous channelized environments and reverse flows of the Delta. As spring flows have fallen, the abundance of many flow-dependent species has drastically declined, and at least one flow-dependent species, longfin smelt, is near extinction. For fish like delta smelt, which prefer water that is just slightly salty, the relocation of their habitat upstream near the Delta puts them at greater risk of being captured by the massive federal and state water project pumps – up to 40% of the delta smelt population is lost this way in some years, putting this species on the brink of extinction as well.

Viewed over the last few decades, the year-in and year-out reductions in freshwater flows from the watershed have created a condition of near constant drought for the Bay. In seven of the last ten years, the amount of precipitation from the Bay-Delta watershed was average or higher than average but, in eight of those same ten years, the amount of fresh water that flowed into the Bay was far less than average, similar to what would have flowed into it in dry or critically dry years. The native species that live in the estuary are well adapted to tolerate periodic drought, but the chronic drought condition now imposed on the Bay by upstream storage and diversions is a major factor in the across the board population declines seen in recent years.



Dams, upstream diversions, and Delta exports have reduced the amount of fresh water that flows into San Francisco Bay. In 2009, barely a third of the total annual runoff from the watershed (dark blue line) actually reached the Bay (light blue line), the third largest reduction in inflows in 80 years. The amount that did flow into the Bay was comparable to natural inflow in a critically dry year.



The abundance of many Bay and Delta fish species is correlated with freshwater flow conditions: the better the flow conditions, the more abundant the fish.

OCEAN CONDITIONS— BLAME IT ON THE WEATHER...

Some people think that ocean conditions are responsible for the decline in our salmon and the Bay-Delta ecosystem as a whole. In the mid-2000s, very poor conditions for nearshore ocean productivity prevailed off the California coast, and these conditions negatively affected the growth and survival of young Chinook salmon entering the ocean. But populations of salmon and other migratory fish species have been in decline for decades, including long periods when ocean conditions were highly productive, and have continued to decline even as ocean conditions improved in the years following the mid-2000s. Furthermore, many of the Bay-Delta species that are declining live in the estuary year round, and are relatively unaffected by changes in ocean conditions. Humans have changed conditions far more in the Bay-Delta ecosystem – the nursery habitat for many marine species - than in the ocean, and we can do far more to support thriving populations of these species by restoring flow and habitat throughout the estuary and its watershed than by trying to change ocean conditions!

RESTORING THE INDISPENSABLE ELEMENT:
WHAT WILL IT TAKE TO RESTORE FRESHWATER FLOWS?

The Bay-Delta estuary and its watershed is one of the most intensively studied systems in the world and decades of research provide more than enough information about the rates and patterns of flows needed to begin restoring the ecosystem. Unfortunately, most of the existing flow requirements adopted by state and federal governments for flows in the Bay-Delta system are designed only to prevent species and habitats from disappearing completely. Much more in the way of flow restoration is needed to restore the estuary and its watershed to healthy ecosystems with thriving species and habitats. This section lays out some of the most important elements of an overall flow regime that can help accomplish that end. It is imperative to begin to meet flow restoration targets as often as possible and in as many regions as possible if we are to save the treasure that is the Bay-Delta.

MOUNTAIN STREAMS

The single most important approach to improving flows in the Bay-Delta's upper watershed is to reconnect mountain streams to their downstream reaches by removing barriers to flow and fish passage whenever possible. Removing these barriers and allowing the continuous flow of water and sediment will improve downstream water quality, replenish salmon spawning gravels, restore desirable flow levels and variations, and increase the amount of habitat accessible to salmon and other species.

- Remove obsolete and deteriorating dams in the upper watersheds, and ensure adequate fish passage on all other dams by installing fish ladders, fish lifts, or other types of access.
- Set stream flow requirements that reproduce natural runoff patterns, maintain tolerable water temperatures, and support sufficient habitat area and quality for all river reaches that can be accessed by salmon and other aquatic species. Limit on-stream diversions and local groundwater extractions to ensure compliance with these requirements.

In 2000, Saeltzer Dam on Clear Creek, a tributary of the Sacramento River, was removed and the river channel restored. This mountain stream now supports a growing population of spring-run Chinook salmon. | *Both photos courtesy of Diana Jacobs, SRPT*

LOWLAND RIVERS

The solutions for lowland rivers differ depending on their location in the Sacramento or San Joaquin Valleys. A great deal of water moves through the Sacramento River basin, but the seasonal timing of river flow is the fundamental problem. More of the water that is currently held back behind large dams until the summer and fall irrigation season needs to be allowed to flow in late winter and spring in order to inundate floodplains, establish riparian vegetation, and support a diverse aquatic community. In addition, some stored water needs to be conserved to provide flows to support cool water temperatures for salmon and steelhead that are spawning and rearing below the dams.

In contrast, very little flow is allowed to escape from the San Joaquin Valley. To begin restoring the San Joaquin ecosystem, we should always provide minimum streamflows that are needed to allow successful fish migration and inundate floodplains. If such minimum flows were provided in all years, they would restore the connection between these rivers, their flooplains and the downstream environments of the Delta, San Francisco Bay and the ocean.

- Provide sufficient river flows to inundate floodplains on the valley floor in the late winter and early spring for two weeks to three months, depending on how much runoff is occurring.
- Maintain flows on the lower San Joaquin River as it enters the Delta during the spring snowmelt period in excess of 5,000 cubic feet per second, the minimum level needed to ensure that enough salmon migrate to the ocean and return to spawn, and increase these flows proportionately as runoff increases.

- Release sufficient amounts of water to provide stranded migratory fishes with cool water holding and spawning habitats below the dams throughout the summer and fall.

THE DELTA

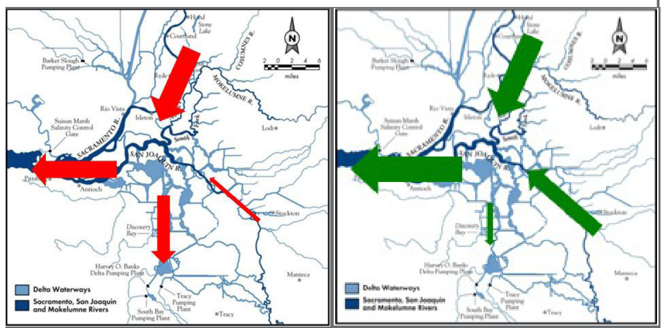
Restoring flows in the rivers feeding into the Delta is critical to restoring the Delta ecosystem – but that will only go so far if conditions in the Delta itself do not improve. Much must also be done to render this critical junction point of the watershed a safe place for fish and wildlife. The most direct and effective way of doing so is to eliminate or reduce the unnatural and harmful net reverse flows in Delta and lower river channels by controlling the rate of export pumping by the massive state and federal water project pumps, relative to Delta inflows, particularly during the ecologically important winter and spring spawning and migration seasons. These pumping controls should be combined with near- and long-term changes to the physical Delta. In the near term, eliminating manmade cross channels between the Delta's different inflowing rivers, and other changes to channel configurations, could improve channel flow patterns. In the long term, restoration of complex marsh channels and other habitats should also improve the movement and circulation of freshwater flows.

- Maintain a net downstream (positive) flow in Delta channels during the winter and spring periods, especially during dry years and when spawning populations of sensitive species like delta smelt are low or declining. Under all conditions, restrict net reverse (negative) flows to relatively low rates (less than -1,500 cubic feet per second, as opposed to the recent historical levels of -8,000 cfs and current regulatory caps of -5,000 cfs) to prevent significant losses of fish to pumping and habitat degradation.
- Limit the amount of water that can be exported by the Delta pumps in the critical spring fish migration period to a fraction of the amount flowing in from the San Joaquin River (about 25%)to eliminate reverse flows in the lower river channels and protect resident and migrating juvenile fishes.
- During the summer and fall, restrict reverse flows to less than -5,000 cfs to prevent the plankton blooms – the food supply for the next year's fish population – from being removed from the Delta by the export pumps.

SAN FRANCISCO BAY

Increasing freshwater flows into the Bay during the late winter and spring is the single most comprehensive and effective action that can be taken to restore the estuarine ecosystem. Dedicating a higher percentage of runoff from the Bay's watershed to these inflows will increase the numbers of fish, shrimp, plankton and other creatures. It will restore both seasonal and year-to-year variability, rescuing the ecosystem from the chronic, man-made drought of recent years and discouraging the spread of introduced species that thrive in more stable and degraded environments. Increasing fresh water flow to the Bay on a smaller scale in the later summer and fall is also desirable to help maintain a minimum amount of habitat for delta smelt and other species as runoff dwindles and upstream diversions increase.

- Provide average freshwater inflows to the Bay during the winter and through the spring of about 75 percent of the natural runoff from the watershed. This translates roughly to the amount of flow needed to ensure low salinity habitat in the upper reaches of San Francisco Bay throughout the critical spawning and migration and to reproduce the desirable conditions for productivity and growth in the estuary that existed in the two decades before aquatic populations began to decline in the 1980s.
- Maintain sufficient Bay inflows in the late summer and fall except when runoff conditions are relatively dry to prevent saltwater intrusion into the Delta, ensuring that enough productive, brackish water habitat is available for resident fish species and reducing their exposure to hazardous reverse flows in the Delta.



Today Future?

Inflows to the Delta and Bay have been sharply reduced and extreme reverse flows from Delta pumping have become the norm in recent decades (left). A recent report by the State of California confirms long-standing recommendations by The Bay Institute to dramatically increase inflows and curtail reverse flows (right).

MEETING CALIFORNIA'S NEEDS WITHOUT SACRIFICING THE BAY-DELTA

There is more than enough water to restore the Bay-Delta ecosystem and still meet the water supply needs of Californians in the 21st century – we need only follow three basic principles for managing California's water supply:

- All users of water in California must contribute their fair share of water to restoring ecosystem flows, and be held to account for meeting water conservation targets.
- Each unit of water supply must be made to work harder through reuse, recycling and other means.
- California must base its water management on the realities of a 21st century climate.

FAIR SHARE

In California, water – and the ecosystems it supports – are public trust resources. They belong to all of us, and all of us have a responsibility to protect them. Whether through residential use, in business, or in growing and/or consuming crops, all Californians have contributed to degrading the aquatic environments of the state, including the Bay-Delta system. But not all Californians contribute equally to causing or solving the problem. Cities and irrigation districts with senior water rights often have less or no obligations to release water for environmental protections than more junior water rights holders or those who purchase water from the federal and state water projects. These senior water rights holders have abundant tools available to use water more efficiently and achieve the same results with far less water; they simply have little incentive to do so, and, in some cases, a contrary incentive to keep using excessive amounts of water. Assessing a fair, pro rata share contribution from all water users in the Bay-Delta system could generate millions of acre-feet of water to restore freshwater flows and save the estuarine ecosystem, while spreading the public trust obligation among a larger group and diminishing the responsibility of any one user for doing so.

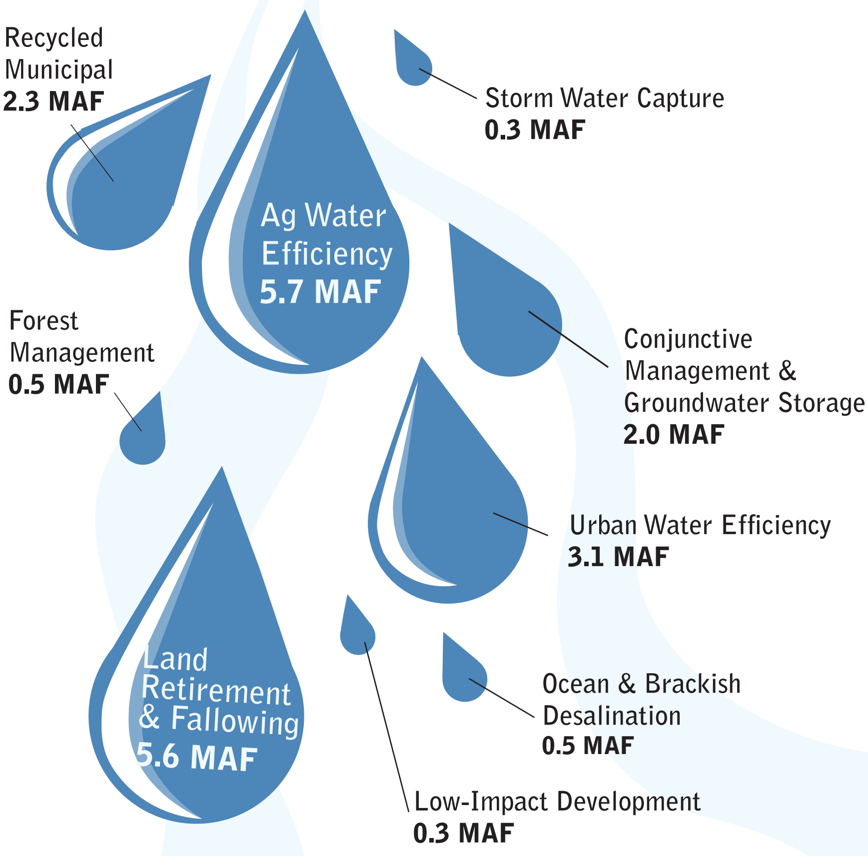
Urban residents generally pay a higher cost for water and invest more in conserving it than do agricultural growers, who consume most of the state's developed water supplies, pay less for it, and disproportionately impact aquatic environments. Furthermore, not all sectors of water use are held to the same or equivalent targets for conserving water. The state's recently adopted target of reducing per capita water use in the urban sector by 20% should be matched by similar commitments for agricultural water users, and investments in new water projects and programs conditioned on the ability to meet the targets.

GETTING MORE BENEFIT FROM EACH DROP OF WATER

Relying on high levels of water diversion from the Delta and its watershed is not only environmentally damaging, it is not a cost-efficient or reliable way of meeting our state's future water needs. The most sustainable approaches to managing water supplies wisely involve using less water while providing the same goods and services (water efficiency, conservation), using water more than once before disposing of it (recycling), cleaning up degraded water so that it can be used for productive purposes (brackish water reclamation), and storing water underground in our natural reservoirs (groundwater aquifers) during wet years (conjunctive use, water banking, stormwater recharge). Proven and practicable technologies exist to implement all of these approaches, with costs dropping as each technology becomes more widely adopted and perfected. Targets for achieving water savings from regional reuse, recycling and other conservation programs should be adopted as appropriate for each area of the state.

Making each drop of water do more means healthy rivers and a healthy economy can coexist

Although California has made significant progress in using water more efficiently in the last 20 years, there is still great potential for using the existing supplies even more efficiently and increasing the amount and reliability of dry year supplies through a wide variety of measures. The total of all these measures is equal to about half of the current withdrawals, enough to accommodate future growth and reduce our reliance on the Delta and other aquatic ecosystems. Nearly all these measures are less expensive and environmentally and politically less disruptive than building new surface storage, and many have the added benefit of reducing energy costs and improving water quality.



The sum of all these water efficiency measures is equal to about half of the total water demand in the State today, enough to accommodate future growth and reduce our reliance on the Delta and other aquatic ecosystems. Nearly all these measures are less expensive and environmentally and politically less disruptive than building new surface storage, and many have the added benefit of reducing energy costs and improving water quality.

MONO LAKE— WE CAN DO IT TOO

Mono Lake, a unique ecosystem on the eastside of the Sierra Nevada, was once in danger of shrinking to a sterile sump as a result of massive water diversions by the city of Los Angeles. Since 1989, however, L.A.'s water supplies from the eastern Sierra have been reduced by about 30% to restore Mono Lake, its tributaries and the Lower Owens River. L.A. was able to absorb these reductions primarily by investing in water conversation and recycling and its water use today is similar to what it was 25 years ago – despite a 30% increase in population. It's a win-win solution: eastern Sierra aquatic ecosystems are being restored, the local tourist economy is invigorated, and L.A. committed to meet any increase in its water demand in the next 20 years by continuing to invest in water efficiency programs rather than importing new water from this or other watersheds.

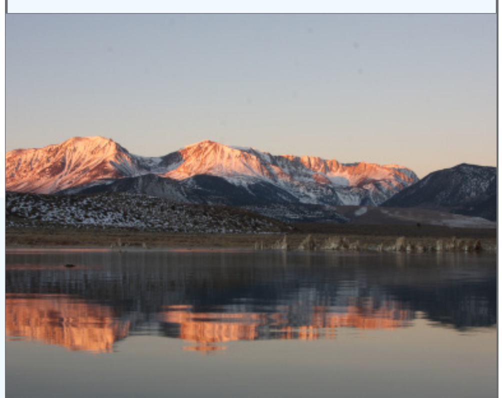


Photo courtesy of the Mono Lake Committee & Arya Degenhardt

Photo courtesy of David Sanger

MANAGING FOR A 21ST CENTURY CLIMATE

As global warming changes California's climate, the state's management of its water resources will have to adapt to conditions where more runoff will come in the form of winter flood flows and less as spring snowmelt, where energy generation must comply with targets for reducing carbon emissions, and where already endangered species and ecosystems will be further stressed by rapid habitat change. California's existing water system, with its massive infrastructure for capturing snowmelt and conveying water across long distances, lack of groundwater monitoring and management, and Byzantine code of water law was designed for the world of the late 19th and early 20th centuries. Its creators assumed that future hydrological conditions would mirror the less variable and cooler past we have come to take for granted; they ignored the needs of aquatic environments; and they imagined an endless supply of cheap energy. This system must evolve in three major ways if our state is to exploit the changed circumstances of a warming world to maintain adequate supplies for public health and economic and environmental viability.

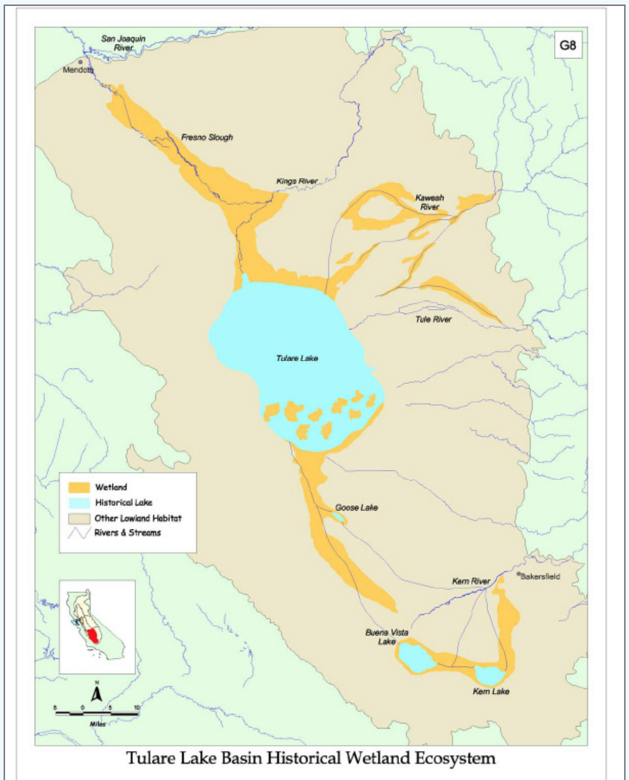
First, we must reduce our reliance on imported sources of water with their high economic, environmental and energy costs, transitioning instead to a policy of regional self-sufficiency, based on the immense potential for local water savings from reuse, recycling, and other conservation technologies.

Second, we must know how much water we use and how much energy it takes to capture and deliver it. Many areas do not measure surface or groundwater use at all. Leaks and unaccounted use can represent 10% or more of total urban use in some areas that measure water use. And the energy use associated with water can be enormous – the California State Water Project's transport of water from the Sierra to areas south of the Delta alone represents about 3% of California's total energy consumption. Water-related energy use consumes 19 percent of the state's electricity, 30 percent of its natural gas, and 88 billion gallons of diesel fuel every year.

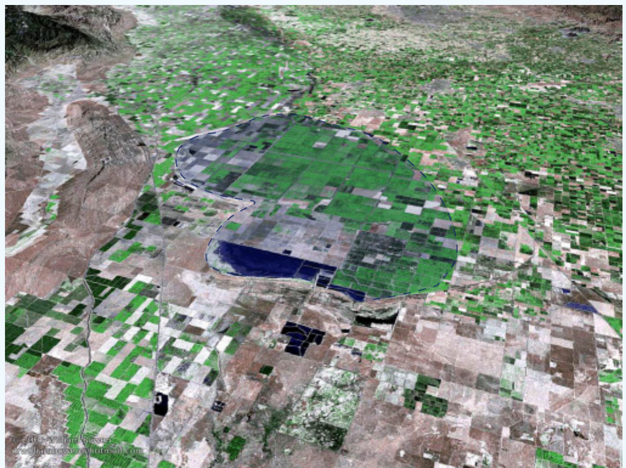
Third, we must increase our ability to capture and store water using elements of natural design, letting the water go where it wants to and using the natural capacity of groundwater basins to clean and store water for later use. Why spend millions capturing, treating and disposing of stormwater runoff as "wastewater" when we can allow stormwater to naturally infiltrate into the groundwater and reuse it? Existing reservoirs and expanded flood basins and floodways can temporarily capture more of the peak flood flows that will be typical of a warming climate and then divert these flows to groundwater recharge areas.

TULARE LAKE:
A 21ST CENTURY WATER FACILITY?

One hundred and fifty years ago, Tulare Lake in the Southern San Joaquin Valley was the largest lake west of the Mississippi River, a major stopover for migratory birds, and an important fishery for Native Americans and early settlers. Although now completely drained and farmed for mostly annual crops like cotton and alfalfa, the lake bottom is still periodically flooded despite efforts to redirect the runoff to other areas. Instead, the Tulare Lake bottom could be used on a regular basis to temporarily store flood flows from its own watershed and, by using existing aqueducts, from other watersheds when their reservoirs are full. This stored water could be used to support restoration of the lake as a fish and wildlife sanctuary and later delivered to local water users. This approach takes advantage of the realities of our emerging climate, where runoff will occur less as prolonged and steady snowmelt and more as episodic flooding events, and allows for environmental and water supply purposes to be pursued together.



Tulare Lake and other flood basin lakes in the Southern San Joaquin Valley occupied nearly 900 square miles in the 19th century. Tulare Lake was the largest lake west of the Mississippi River and was a source of fish, waterfowl, and turtles for California residents.



Surplus water from the Delta and the Sierra rivers is currently stored at the south end of the former Tulare Lake bottom. Expanding these storage areas could provide water supply, flood control, and habitat benefits.

GOING AFTER THE FLOW

Since 1981, The Bay Institute has worked to protect, restore, and inspire conservation of San Francisco Bay and its watershed. One of the highest priorities in achieving that mission has been the effort to identify and secure the freshwater flow regimes needed to prevent ecological collapse and species extinctions and, over the long term, restore the estuary's fish and wildlife populations and habitats to a healthy condition. The Bay Institute's campaign to increase flows and restore the natural pattern of runoff throughout the estuary reaches the entire watershed, from the Sierra to the Sea.

MOUNTAIN STREAMS

Dams on almost every river and stream have blocked access to the clean, coldwater habitats essential for fish spawning – as well as blocking the flow itself.

- The Bay Institute's scientists successfully argued in federal court that permits for upstream dams issued by the National Marine Fisheries Service were failing to dedicate sufficient flows to ensure tolerable temperature conditions and fish passage for migrating salmon and steelhead. In 2009, new permits were issued that helped fill these gaps in protection. We are also advising the federal and state governments on recovery planning efforts for fish species that use these upper watersheds.

- There are efforts underway to construct even more large dams. The Bay Institute is working to educate decision-makers and the public about the environmental and economic problems associated with proposed new projects like Temperance Flat Dam on the San Joaquin River.

LOWLAND RIVERS

Natural runoff patterns have been completely transformed in the major river systems of the Central Valley, with peak winter and spring flows shifted to less ecologically important periods later in the year on the Sacramento River system and virtually eliminated on the San Joaquin system.

- The Bay Institute and the Natural Resources Defense Council worked for over twenty years to revive the mainstem San Joaquin River, where massive diversions dewatered the river and destroyed one of the state's largest salmon runs. Under a new agreement with the federal government and water users, restoration of flows and fisheries began in 2009.

- The Bay Institute's analyses of the flow needs of Chinook salmon, Sacramento splittail, and other species were cited in the recent landmark finding by the State Water Resources Control Board confirming the need for sufficient river flows to inundate floodplains and support successful migrations of adult and juvenile fish. Building on this finding, we will work with the Board and fish and wildlife agencies to secure adoption of new river flow regulations and to expand floodplain habitat.

THE DELTA

Reverse (upstream) flows in Delta and lower San Joaquin River channels that result from pumping water for export to the San Joaquin Valley, Southern California and parts of the San Francisco Bay Area destroy hundreds of millions of juvenile fish, eggs, larvae, and other aquatic organisms each year. Export operations must be changed dramatically to prevent extinction of a number of species and begin their road to recovery.

- The Bay Institute's scientists successfully made the case in federal court that the permits for export pumping issued by the U.S. Fish and Wildlife Service and the National Marine Fisheries Service were utterly failing to prevent the extinction of delta smelt, Chinook salmon, and steelhead. As a result, new federal protections were adopted in 2008 and 2009 that go a long way toward limiting reverse flows. We are pursuing additional federal and state protections to prevent export pumping from harming other species not covered by the current regulations.

- In enacting the Sacramento – San Joaquin Reform Act of 2009, the California Legislature adopted a new state policy to reduce reliance on the Delta as a source of water supply and set aggressive new urban water conservation requirements. The Bay Institute, which helped draft and pass the legislative reforms, is working to develop matching targets for agricultural water conservation and identify promising new projects to promote regional self-sufficiency in areas that currently export water from the Delta.

SAN FRANCISCO BAY

Over half of winter and spring runoff in the estuary's watershed is diverted before reaching the Bay. Increasing the flow of fresh water to the Bay is the single most comprehensive and effective action that can be taken to restore vital brackish water habitat and recreate the flow conditions that allow estuarine species to rebound and flourish.

- The Bay Institute's analyses of the Bay inflows needed for ecosystem recovery and restoration were cited as the basis of the recent landmark finding by the State Water Resources Control Board confirming that about 75% of the runoff from the watershed is needed to protect the Bay's species and habitats. We will work with the Board, the new Delta Council created by the 2009 Reform Act, and fish and wildlife agencies charged with protecting the estuary to adopt new requirements that help meet this target.

- Longfin smelt, once the most abundant fish species in the estuary, is now one of the rarest. This species plays an important role in the food web of the entire estuarine ecosystem. The Bay Institute successfully petitioned the State of California to list longfin as an endangered species and is actively seeking federal protection for the species as well. Protection of longfin smelt is closely tied to providing adequate winter and spring Bay inflows.

REFERENCES

Gone with the Flow uses information and data from a variety of sources, including The Bay Institute's three decades of scientific and policy work in the San Francisco Bay-Delta estuary and its watershed. Sources that document specific findings and provide additional background information are listed below for each section of the report. Useful websites and data sources are listed separately at the end.

THE SAN FRANCISCO BAY-DELTA ESTUARY: A FRESHWATER RIVER RUNS THROUGH IT

The Bay Institute. 1998. From the Sierra to the Sea: An Ecological History of the San Francisco Bay-Delta Watershed. Available at http://bay.org/publications/sierra-to-the-sea

The Bay Institute. 2003 and 2005 Ecological Scorecards, San Francisco Bay Index. Reports and technical appendices available at: http://bay.org/publications/%C2%ADecological-scorecards

The Bay Institute. 2004. The Year in Water 2003. Available at: http://bay.org/publications/%C2%ADreports

California Department of Fish and Game. 2010. 2010 Ocean Salmon Season Setting Process Begins, Chinook Numbers Continue to Decline. Press release, February 11, 2010.
Available at: http://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=17929

California Department of Water Resources. 2009. California Water Plan Update 2009. Bulletin 160-09, available at: http://www.waterplan.water.ca.gov/cwpu2009/index.cfm

California State Lands Commission. 1993. California's Rivers: A Public Trust Report.
Available at: http://www.slc.ca.gov/Reports/CA_Rivers_Rpt.html

Sommer, T., C. Armor, R. Baxter, R. Breuer, L. Brown, M. Chotkowski, S. Culberson, F. Feyrer, M. Gingras, B. Herbold, W. Kimmerer, A. Mueller-Solger, M. Nobriga, and K. Souza. 2007. The collapse of pelagic fishes in the upper San Francisco Estuary. Fisheries 32:270-277.

State Water Resources Control Board. 2010. 2010 Integrated Report, Clean Water Act Sections 303(d) and 305(b). Available at: http://www.waterboards.ca.gov/water_issues/programs/tmdl/integrated2010.shtml

U. S. Fish and Wildlife Service. 1995. Working Paper on restoration needs: habitat restoration actions to double natural production of anadromous fish in the Central Valley of California. Volume 3. May 9, 1995. Prepared for the U. S. Fish and Wildlife Services under the direction of the Anadromous Fish Restoration Program Core Group. Stockton, CA.

BOX: Freshwater Flow vs. "Other Stressors": The Debate That's Not

Dugdale, R.C., F. P. Wilkerson, V.E. Hogue, and A. Marchi. 2007. The role of ammonium and nitrate in spring bloom development in San Francisco Bay. Estuarine Coastal and Shelf Science. 73:17-29.

Delta Environmental Flows Group Introductory Presentation to the State Water Resources Control Board's Delta Flow Criteria proceedings, March 26, 2010. Available at: http://www.swrcb.ca.gov/waterrights/water_issues/programs/bay_delta/deltaflow/defg_presentation.shtml

FRESHWATER FLOW: THE INDISPENSABLE ELEMENT

California Department of Fish and Game. 2010. State and Federally Listed Endangered and Threatened Animals of California. Available at: http://www.dfg.ca.gov/biogeodata/cnddb/pdfs/TEAnimals.pdf

BOX: Water Quality vs. Water Quantity

Baxter, R., R. Breuer, L. Brown, M. Chotkowski, F. Feyrer, M. Gingras), B. Herbold, A. Mueller-Solger, M. Nobriga, T. Sommer, and K. Souza. 2008. Pelagic Organism Decline Progress Report: 2007 Synthesis of Results.
Available at: http://www.fws.gov/sacramento/es/documents/POD_report_2007.pdf

Dugdale, R.C., F. P. Wilkerson, V.E. Hogue, and A. Marchi. 2007. The role of ammonium and nitrate in spring bloom development in San Francisco Bay. Estuarine Coastal and Shelf Science. 73:17-29.

MOUNTAIN STREAMS

The Bay Institute. 1998. From the Sierra to the Sea: An Ecological History of the San Francisco Bay-Delta Watershed. Available at http://bay.org/publications/sierra-to-the-sea

Lindley, S. T., R. S. Schick, A. Agrawal, M. Goslin, T. E. Pearson, E. Mora, J. J. Anderson, B. May, S. Greene, C. Hanson, A. Low, D. McEwan, R..B. MacFarlane, C. Swanson, and J. G. Williams. 2006. Historical population structure of Central Valley steelhead and its alteration by dams. San Francisco Estuary and Watershed Science 4(1) Article 3.

McEwan D. R.. 2001. Central Valley steelhead. In: Brown R. L., editor. Fish Bulletin 179. Contributions to the biology of Central Valley salmonids. Vol. 1. Sacramento (CA): California Department of Fish and Game. Pg. 1–43.

Yoshiyama, R .M., E. R. Gerstung, F. W. Fisher, and P. B. Moyle. 2000. Chinook salmon in the California Central Valley: an assessment. Fisheries 25(2):6-20.

BOX: Can You Restore Wetlands Without Water?

The Bay Institute. 1998. From the Sierra to the Sea: An Ecological History of the San Francisco Bay-Delta Watershed. Available at http://bay.org/publications/sierra-to-the-sea

LOWLAND RIVERS

The Bay Institute. 1998. From the Sierra to the Sea: An Ecological History of the San Francisco Bay-Delta Watershed. Available at http://bay.org/publications/sierra-to-the-sea

The Bay Institute. 2010. Exhibit 3: Delta Inflows. Written testimony submitted to the State Water Resources Control Board Delta Flow Criteria Proceedings.
Available at: http://www.bay.org/assets/Bay-Delta%20Flow%20Criteria%20Exhibit%203.pdf

California Department of Fish and Game. 2010. Flows Needed in the Delta to Restore Anadromous Salmonid Passage from the San Joaquin River at Vernalis to Chipps Island. Written testimony submitted to the State Water Resources Control Board Delta Flow Criteria Proceedings.
Available at: http://www.swrcb.ca.gov/waterrights/water_issues/programs/bay_delta/deltaflow/docs/exhibits/dfg/dfg_exh3.pdf

DeRobertis, A., C. H. Ryer, A. Veloza, and R. D. Brodeur. 2003. Differential effects of turbidity on prey consumption of piscivorous and planktivorous fish. Canadian Journal of Fisheries and Aquatic Science 60:1517-1526.

Jeffres, C. A., J. J. Opperman and P. B. Moyle, 2008. Ephemeral floodplain habitats provide best growth conditions for juvenile Chinook salmon in a California river. Environmental Biology of Fishes 83:449-458.

Kondolf, G. M. 2000. Changes in flow regime and sediment budget in the Sacramento-San Joaquin River system since 1850: implications for restoration planning. Presented at CALFED Bay-Delta Program Science Conference, Oct. 3-5, 2000, Sacramento, CA. Abstract (#67), summary, and notes available at http://www.iep.water.ca.gov/calfed/sciconf/2000/publications/http://www.iep.water.ca.gov/calfed/sciconf/2000/publications/

May, J. T., and L. R. Brown. 2002. Fish communities of the Sacramento River Basin: implications for conservation of native fishes in the Central Valley, California. Environmental Biology of Fishes 63:373–388.

Moyle, P.B. 2002. Inland Fishes of California. University of California Press. Berkeley, CA.

National Marine Fisheries Service. 2009. Public Draft Recovery Plan for the Evolutionarily Significant Units of Sacramento River Winter-Run Chinook Salmon and Central Valley Spring-Run Chinook Salmon and the Distinct Population Segment of

Central Valley Steelhead. National Oceanic and Atmospheric Administration, NMFS Southwest Regional Office. Available at: http://www.nmfs.noaa.gov/pr/recovery/plans.htm

Sommer, T., R. Baxter, and B. Herbold 1997. Resilience of splittail in the Sacramento-San Joaquin Estuary. Transactions of the American Fisheries Society 126:961-976.

Sommer, T. R., M. L. Nobriga, W. C. Harrell, W. Batham, and W. J. Kimmerer. 2001. Floodplain rearing of juvenile Chinook salmon: evidence of enhanced growth and survival. Canadian Journal of Fisheries and Aquatic Sciences 58:325-333.

Sommer, T.R., L. Conrad, G. O'Leary, F. Feyrer, and W. C. Harrell 2002. Spawning and Rearing of Splittail in a Model Floodplain Wetland. Transactions of the American Fisheries Society 131: 966-974

Sommer, T.R., W. C. Harrell, A. Mueller-Solger, B. Tom, and W. Kimmerer. 2004. Effects of flow variation on Channel and floodplain biota and habitats of the Sacramento River, California, USA. Aquatic conservation: Marine and freshwater ecosystems, 14: 247-26

THE DELTA

The Bay Institute. 1998. From the Sierra to the Sea: An Ecological History of the San Francisco Bay-Delta Watershed. Available at http://bay.org/publications/sierra-to-the-sea

The Bay Institute, et al. 2007. A Long Term Vision for the Sacramento-San Joaquin Delta: A Work in Progress. Written comments submitted to the Delta Vision Blue Riboon Task Force. Available at: http://bay.org/assets/DeltaVision.pdf

The Bay Institute. 2008. Written comments and presentation submitted to the State Water Resources Control Board for the Pelagic Organism Decline proceedings.
Available at: http://www.swrcb.ca.gov/waterrights/water_issues/programs/bay_delta/pelagic_organism/index.shtml

The Bay Institute. 2010. Exhibit 1: General Analytical Framework for Developing Public Trust Flow Criteria. Written testimony submitted to the State Water Resources Control Board Delta Flow Criteria Proceedings.
Available at: http://www.bay.org/assets/Bay-Delta%20Flow%20Criteria%20Exhibit%201.pdf

The Bay Institute. 2010. Exhibit 4: Delta Hydrodynamics. Written testimony submitted to the State Water Resources Control Board Delta Flow Criteria Proceedings. Available at: http://www.bay.org/assets/Bay-Delta%20Flow%20Criteria%20Exhibit%204.pdf

Groot, C. and L. Margolis. 1991. Pacific Salmon Life History. UBC Press, Vancouver, BC. 530 pp.

Kimmerer, W. 2008. Losses of Sacramento River Chinook salmon and delta smelt to entrainment in water diversions in the Sacramento-San Joaquin Delta. San Francisco Estuary and Watershed Science Vol. 6, Issue 1, Article 4. Available at: http://escholarship.org/uc/item/7v92h6fs#page-1

Kimmerer, W.J., M.L. Nobriga. 2008. Investigating particle transport and fate in the Sacramento-San Joaquin Delta using a particle tracking model. San Francisco Estuary and Watershed Science 6(1): [Article 4]. Available at: http://escholarship.org/uc/item/547917gn#page-1

Moyle, P.B. 2002. Inland Fishes of California. University of California Press. Berkeley, CA.

BOX: People Don't Kill Fish, Fish Kill Fish?

Baxter, R., R. Breuer, L. Brown, M. Chotkowski, F. Feyrer, M. Gingras), B. Herbold, A. Mueller-Solger, M. Nobriga, T. Sommer, and K. Souza. 2008. Pelagic Organism Decline Progress Report: 2007 Synthesis of Results. Available at: http://www.fws.gov/sacramento/es/documents/POD_report_2007.pdf

Moyle, P.B. 2002. Inland Fishes of California. University of California Press. Berkeley, CA.

National Marine Fisheries Service. 2009. Biological and Conference Opinion on the Long-Term Operations of the Central Valley Project and State Water Project. Available at: http://swr.nmfs.noaa.gov/ocap.htm

National Marine Fisheries Service. 2009. Public Draft Recovery Plan for Sacramento River Winter-run Chinook Salmon, Central Valley Spring-run Chinook Salmon and Central Valley Steelhead. National Oceanic and Atmospheric Administration, NMFS Southwest Regional Office. Available at: http://www.swr.noaa.gov/recovery/centralvalleyplan.htm

SAN FRANCISCO BAY

The Bay Institute, et al. 2007. A Long Term Vision for the Sacramento-San Joaquin Delta: A Work in Progress. Written comments submitted to the Delta Vision Blue Ribbon Task Force. Available at: http://bay.org/assets/DeltaVision.pdf

The Bay Institute. 2010. Exhibit 2: Delta Outflows. Written testimony submitted to the State Water Resources Control Board Delta Flow Criteria Proceedings.
Available at: http://www.bay.org/assets/Bay-Delta%20Flow%20Criteria%20Exhibit%202.pdf

California Department of Fish and Game. 2009. Report To the Fish and Game Commission: A Status Review of the Longfin Smelt (Spirinchus thaleichthys) in California . January 29, 2009. California Resources Agency, Sacramento, CA. Available at: nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=10263

Jassby, A. D., W. J. Kimmerer, S. G. Monismith, C. Armor, J. E. Cloern, T. M. Powell, J. R. Schubel and T .J. Vendlinksi 1995. Isohaline position as a habitat indicator for estuarine populations. Ecological Applications. 5:272-289.

Kimmerer, W. J. 2002. Effects of freshwater flow on abundance of estuarine organisms: physical effects or trophic linkages? Marine Ecology Progress Series 243:39-55.

Kimmerer, W. 2004. Open Water Processes of the San Francisco Estuary: From Physical Forcing to Biological Responses. San Francisco Estuary and Watershed Science. Vol. 2, Issue 1 (February 2004), Article 1.
Available at: http://repositories.cdlib.org/jmie/sfews/vol2/iss1/art1.

Kimmerer, W. 2008. Losses of Sacramento River Chinook salmon and delta smelt to entrainment in water diversions in the Sacramento-San Joaquin Delta. San Francisco Estuary and Watershed Science Vol. 6, Issue 1, Article 4.
Available at: http://escholarship.org/uc/item/7v92h6fs#page-1

Kimmerer, W. J., E. S. Gross and M. L. Williams. 2009. Is the response of estuarine nekton to freshwater flow in the San Francisco Estuary explained by variation in habitat volume? Estuaries and Coasts 32:375-389.
Available at: http://online.sfsu.edu/~kimmerer/Files/KimmererEtAl2009EstuariesCoasts.pdf

Rosenfield, J.A. and R.D. Baxter. 2007. Population dynamics and distribution patterns of longfin smelt in the San Francisco Estuary. Transactions of the American Fisheries Society 136:1577–1592.

Sommer, T., C. Armor, R. Baxter, R. Breuer, L. Brown, M. Chotkowski, S. Culberson, F. Feyrer, M. Gingras, B. Herbold, W. Kimmerer, A. Mueller-Solger, M. Nobriga, and K. Souza. 2007. The collapse of pelagic fishes in the upper San Francisco Estuary. Fisheries 32:270-277.

BOX: Ocean Conditions – Blame it on the Weather

Lindley, S. T., C. B. Grimes, M. S. Mohr, W. Peterson, J. Stein, J. T. Anderson, L.W. Botsford, , D. L. Bottom, C. A. Busack, T. K. Collier, J. Ferguson, J. C. Garza, A. M. Grover, D. G. Hankin, R. G. Kope, P. W. Lawson, A. Low, R. B. MacFarlane, K. Moore, M. Palmer-Zwahlen, F. B. Schwing, J. Smith, C. Tracy, R. Webb, B. K. Wells and T. H. Williams. 2009. What caused the Sacramento River fall Chinook stock collapse? Pre-publication report to the Pacific Fishery Management Council, March 18, 2009. Available at: http://swr.nmfs.noaa.gov/media/SalmonDeclineReport.pdf

RESTORING THE INDISPENSIBLE ELEMENT: WHAT WILL IT TAKE TO RESTORE FRESHWATER FLOWS?

The Bay Institute. 2010. Exhibit 1: General Analytical Framework for Developing Public Trust Flow Criteria. Written testimony submitted to the State Water Resources Control Board Delta Flow Criteria Proceedings.
Available at: http://www.bay.org/assets/Bay-Delta%20Flow%20Criteria%20Exhibit%201.pdf

The Bay Institute. 2010. Exhibit 2: Delta Outflows. Written testimony submitted to the State Water Resources Control Board Delta Flow Criteria Proceedings.
Available at: http://www.bay.org/assets/Bay-Delta%20Flow%20Criteria%20Exhibit%202.pdf

The Bay Institute. 2010. Exhibit 3: Delta Inflows. Written testimony submitted to the State Water Resources Control Board Delta Flow Criteria Proceedings.
Available at: http://www.bay.org/assets/Bay-Delta%20Flow%20Criteria%20Exhibit%203.pdf

The Bay Institute. 2010. Exhibit 4: Delta Hydrodynamics. Written testimony submitted to the State Water Resources Control Board Delta Flow Criteria Proceedings.
Available at: http://www.bay.org/assets/Bay-Delta%20Flow%20Criteria%20Exhibit%204.pdf

Feyrer, F. M.L. Nobriga, T.R. Sommer. 2007. Multidecadal trends for three declining fish species: habitat patterns and mechanisms in the San Francsco Estuary, California, USA. Canadian Journal Fisheries and Aquatic Sciences 64:723-734.

Feyrer, F., M. Nobriga, T. Sommer, and K. Newman. In review. Modeling the effects of future freshwater flow on the abiotic habitat of an imperiled estuarine fish. Submitted to Estuaries and Coasts.

National Marine Fisheries Service. 2009. Public Draft Recovery Plan for Sacramento River Winter-run Chinook Salmon, Central Valley Spring-run Chinook Salmon and Central Valley Steelhead. National Oceanic and Atmospheric Administration, NMFS Southwest Regional Office.
Available at: http://www.swr.noaa.gov/recovery/centralvalleyplan.htm

State Water Resources Control Board. 2010. Development of Flow Criteria for the Sacramento-San Joaquin Delta Ecosystem, Draft Report. Available at: http://www.swrcb.ca.gov/waterrights/water_issues/programs/bay_delta/deltaflow/docs/draft_report072010.pdf

MEETING CALIFORNIA'S NEEDS WITHOUT SACRIFICING THE BAY-DELTA

California Air Resources Board. 2008. Climate Change Scoping Plan, Storm Water Capture. (AB 32 Scoping Plan).
Available at: http://www.arb.ca.gov/cc/scopingplan/scopingplan.htm.

California Department of Water Resources 2005. California Water Plan Update 2005. Ocean and Brackish Desalination (including produced water reclamation): Bulletin 160-05.
Available at: http://www.waterplan.water.ca.gov/previous/cwpu2005/index.cfm

California Department of Water Resources. 2009. California Water Plan Update 2009. Bulletin 160-09.
Available at: http://www.waterplan.water.ca.gov/cwpu2009/index.cfm

California Energy Commission. 2005. Final Staff Report on Water-Energy Relationships.
Available at: http://www.energy.ca.gov/2005publications/CEC-700-2005-011/CEC-700-2005-011-SF.PDF

California State Lands Commission. 1993 California's Rivers: A Public Trust Report.
Available at: http://www.slc.ca.gov/Reports/CA_Rivers_Rpt.html

City of Los Angeles. 2008. Securing L.A.'s Water Supply, 2008 (City of Los Angeles Water Action Plan) available at: http://mayor.lacity.org/stellent/groups/ElectedOfficials/@MYR_CH_Contributor/documents/Contributor_Web_Content/LACITY_004714.pdf

Legislative Analyst's Office. 2008. California's Water: An LAO Primer.
Available at: http://www.lao.ca.gov/2008/rsrc/water_primer/water_primer_102208.aspx.

Los Angeles County Economic Development Corporation (LAEDC). 2008. Where Will We Get the Water? Assessing Southern California's Future Water Strategies. Pg. 32-33.
Available at: http://www.laedc.org/consulting/projects/2008_SoCalWaterStrategies.pdf.

National Audubon v City of Los Angeles (1983) California Supreme Court Decision on the public trust and its application to the protection of Mono Lake and its tributary streams.
Available at: http://www.monobasinresearch.org/images/legal/nassupct.htm

Natural Resources Defense Council and Pacific Institute. 2004. Energy Down the Drain.
Available at: http://www.pacinst.org/reports/energy_and_water/index.htm.

Natural Resources Defense Council and University of California, Santa Barbara. 2009. A Clear Blue Future: How Greening California Cities Can Address Water Resources and Climate Challenges in the 21st Century.
Available at: http://www.nrdc.org/water/lid/

Pacific Institute. 2008. More with Less: Agricultural Water Conservation and Efficiency in California.
Available at: http://www.pacinst.org/reports/more_with_less_delta/index.htm.

Pacific Institute. 2009. Sustaining California Agriculture in an Uncertain Future.
Available at: http://www.pacinst.org/reports/california_agriculture/index.htm

United States v. State Water Resources Control Board (1986) (182 Cal.App.rd 82) –commonly known as the “Racanelli Decision.”

URS. 2002. Final Water Supply Study - Development of Water Supply Alternatives for use in Habitat Restoration for the San Joaquin River. Available at: http://www.restoresjr.net/program_library/05-Pre-Settlement/Water%20Management%20Reports/Final%20Water%20Supply%20Study.pdf

WEBSITES AND DATA SOURCES:

California Data Exchange Center (California Department of Water Resources). Information and data on unimpaired flows, actual flows and water quality conditions in California rivers and streams available at: http://cdec.water.ca.gov/

California Department of Fish and Game, Grandtab dataset for Central Valley Chinook salmon escapement.
Available at: http://www.calfish.org/LinkClick.aspx?fileticket=m%2bQf7Cx2i9Y%3d&tabid=104&mid=524

California Department of Fish and Game, Studies and Surveys for the Bay-Delta Region. Information and survey data on fish abundance and distribution available at: http://www.dfg.ca.gov/delta/data/

California Department of Water Resources, Unimpaired Central Valley Streamflows dataset, 1921-2003. Dataset available on request from the agency.

DayFlow (California Department of Water Resources). Information and data on freshwater inflows and outflows for the Sacramento-San Joaquin Delta available at: http://www.water.ca.gov/dayflow/

Pacific Fishery Management Council. Information on salmon and the salmon fishery available at:
http://www.pcouncil.org/salmon/current-season-management/

U.S Bureau of Reclamation, Central Valley Operations Office. Information on water project operations, water deliveries and fish take at the Delta export facilities available at: http://www.usbr.gov/mp/cvo/

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