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IMPACTS OF THE CALIFORNIA DROUGHT FROM 2007 TO 2009

Juliet Christian-Smith, Morgan C. Levy, and Peter H. Gleick

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Glossary of Acronyms

AF	Acre-Feet
Bay-Delta	San Francisco Bay Sacramento-San Joaquin River Delta
CDEC	California Data Exchange Center
CDFA	California Department of Food and Agriculture
CEC	California Energy Commission
CFS	Cubic-Feet Per Second
CRS	Congressional Research Service
CVP	Central Valley Project
CVPIA	Central Valley Project Improvement Act
DFG	Department of Fish and Game
DOI	Department of the Interior
DWR	Department of Water Resources
EDD	Employment Development Department
ESA	Endangered Species Act
EWA	Environmental Water Account
FMWT	Fall Midwater Trawl
GHG	Greenhouse Gas
GWhrs	Gigawatt-Hours
GRACE	NASA's Gravity Recovery and Climate Experiment
MAF	Million Acre-Feet
NASS	National Agricultural Statistics Service
NDO	Net Delta Outflow
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
OCAP	Operational Criteria and Plan
PFMC	Pacific Fishery Management Council
PUMA	Public Use Microdata Areas
SJV	San Joaquin Valley
SWP	State Water Project
SWRCB	State Water Resources Control Board
WQCP	Water Quality Control Plan
TAF	Thousand Acre-Feet
USBR	U.S. Bureau of Reclamation
USDA	U.S. Department of Agriculture
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
WWD	Westlands Water District

Executive Summary

Droughts can produce a wide range of adverse impacts on diverse economic sectors and environmental conditions depending on their intensity, duration, and location and on the actions taken by those affected. Often, the overall consequences of a drought are not fully understood until some time has passed and comprehensive data are collected and analyzed. A good example is the recent multi-year drought in California from 2007 through 2009. During the drought, there was considerable concern and controversy throughout the state about the nature and severity of water shortfalls, and the impacts on individual communities.

Here, we present updated information on impacts of the recent drought on California's economy and environment, and, where possible, its costs. We also assess what this drought tells us about California's vulnerability to future droughts. The state's growing population, the declining health of ecosystems, and climate change all contribute to rising pressure on water resources. It will be increasingly important to have robust and resilient strategies to cope with these pressures. The recent drought provides a unique opportunity to retrospectively examine how the drought affected different sectors and how those sectors responded, in turn. This information can help improve drought planning and management and, ultimately, help minimize negative impacts of future droughts.

According to the California Department of Water Resources, water years 2007-2009 were the 12th driest three-year period in recorded climatic history (DWR 2010). From a purely hydrological perspective, droughts in the late 1920s, 1970s, and 1980s were more severe. The 2007-2009 drought, however, coincided with a period of increased demands for freshwater, changes in operating rules at reservoirs, and environmental protections that reduced pumping of water from the Sacramento-San Joaquin Delta to state and federal water users south of the Delta (DWR 2010). Among the sectors affected by reduced water availability were agriculture, ecosystem health, and hydropower production. We discuss each in this assessment.

During the drought, there was considerable controversy around the role that environmental protections, and in particular, the Endangered Species Act (ESA), played in the reduced exports to south-of-Delta water users. Some critics contended that environmental protections forced dramatic reductions in water supply that hurt agricultural sector production and employment in the Central Valley. Yet, data and analyses from the California Department of Water Resources and the Congressional Research Service now estimate that legal environmental protections accounted for less than a quarter of the overall reductions in 2009 (Cody et al. 2009). The remaining reductions were related to precipitation and runoff. In addition, the Commissioner of the Bureau of Reclamation and the Congressional Research Service have found that these reductions were not due to the ESA alone but to a wide range of federal and state policies, including the Clean Water Act, the state Porter-Cologne Act, the state Fish and Game Code, and the Central Valley Project Improvement Act. Finally, local differences in water-supply impacts also resulted from the priority of use: some federal water project users – settlement and exchange contractors – received 100% of their desired supplies throughout the drought, while others received only 10% (USBR 2009). As a result, contract priority was a critical factor in the disparity in water deliveries during the drought.

Several factors buffered California's agricultural sector from suffering even worse impacts. Among the coping strategies employed were increased reliance on local groundwater, temporary water transfers among users, fallowing farmland, and the alteration of cropping patterns and changes to the types of crops cultivated. New research has found that the average groundwater depletion rate doubled during the 2006-2010 time period (Famiglietti et al. 2011). For instance, in the wet year of 2006, Westlands Water District pumped around 25,000 acre-feet of groundwater (2% of the district's water supply), while in 2009 the district pumped 480,000 acre-feet groundwater (more than 50% of water supply) (Westlands Water District 2010). Strong demand for California farm products on national and global markets also kept both crop prices and revenue high throughout the drought.

As a result of these complex factors, the state's 81,500 farms and ranches received $34.8 billion in gross revenue for their production in 2009[1] – the third highest year on record and just below the all-time high of $38.4 billion reached during 2008, the second year of the drought (USDA-NASS Agricultural Statistics 2010). The California Department of Food and Agriculture (CDFA 2010) reported that the state's agricultural sales for 2009 ranked behind only 2008 and 2007 as third highest on record.

Statewide, harvested acreage has been declining over the past decade, even during periods of more abundant water. The rate of decline in acreage actually appears to have slowed between 2007 and 2009. Yield fluctuates from year to year, but yield throughout the drought years dropped below 2006 (wet year) levels only once and in a single crop category – in field and seed crops - during the final year of the drought (2009). The average total combined yield of irrigated crops in California was higher during the drought period (2007-2009) than prior to the drought (2000-2006).

A closer study of data from county crop reports and irrigation districts reveals varied responses to drought between and within individual counties. For instance, while the total gross revenue of Fresno County agriculture increased by 2% during the drought years, gross revenue in neighboring Kern and Kings Counties declined by 9% and 19%, respectively. And while Fresno, Kern, and Kings Counties all fallowed land at higher rates during the drought, nearby Tulare County did not. In fact, Tulare County harvested more acres in both 2008 and 2009 than it did in 2006, considered a wet water year.

The drought period coincided with the foreclosure crisis and a national and global recession. From 2005 to 2009, unemployment almost doubled statewide from 5.4% to 11.3%.[2] Michael et al. (2010) found that over the same time period crop production and agricultural support jobs declined by 1.5% (2,500 jobs) to 2.3 % (3,750 jobs) in the San Joaquin Valley. However, U.S.

[1] Our analysis reports changes to the total market value of agricultural products in the state. This is the primary measure that the state and counties use to report the value of agriculture. It should be noted, however, that this measure represents gross, not net, revenue and does not include rising production costs or federal payments, such as crop insurance.

[2] Statewide unemployment rates are calculated by California's Employment Development Department and are available here: http://www.labormarketinfo.edd.ca.gov/?pageid=164

Census data and California Employment Development Department data indicate that many employment sectors saw more severe declines than farming, fishing, and forestry occupations in the San Joaquin Valley, which either remained stable or increased as a percentage of the total jobs available. Notably, unemployment rates rose from 2009 to 2010 in every San Joaquin Valley County, despite greater water supplies in 2010 (EDD 2005-2010). Recent attention to the human suffering in this region highlights the problem of severe and chronic poverty in the Valley, ironically one of the highest grossing agricultural regions in the world. Communities within the San Joaquin Valley have had the highest levels of unemployment and poverty in the state for decades, in both wet and dry years (CRS 2005).

We also examine the impact of the drought on the environment, which includes fisheries and associated economies. Environmental impacts are difficult to disaggregate from natural fluctuations and other anthropogenic factors (land use, climate change, etc.) that contribute to the degradation of California's aquatic ecosystems. But, there are several environmental indicators that have been consistently tracked over the years that allow us to examine evidence of drought stress within longer-term trends, including the salinity of the Sacramento-San Joaquin Delta, environmental flows for waterfowl and wildlife refuges, and fisheries. Our review of these data indicates that the drought led to significant declines in native fish populations and a collapse in related industries. Fish populations naturally fluctuate over time, yet certain species have experienced significant population declines over the past decade, and record lows can be seen in the 2007-2009 drought years. During the drought, the California Department of Fish and Game (DFG) found that Delta smelt, longfin smelt, American shad, and threadfin shad populations all were at record low levels; in 2010, striped bass and splittail populations plunged to record lows as well (in two of the past three years, zero splittail were collected in annual surveys) (DFG 2010).

The quantities of Chinook salmon caught off the coast of California have been in decline for the past several decades. Between 1960 and 1980, commercial catch averaged 7.7 million pounds per year. Between 1980 and 2000, the catch averaged 5.2 million pounds per year. Catch average during the past decade declined even further to 3.9 million pounds per year. In 1990, during the middle of the last major drought, the salmon harvest was 4.4 million pounds. Harvests during the most recent drought were much less: only 1.5 million pounds were landed during the first year of the drought (2007), and then the fisheries were closed completely during 2008 and 2009. Preliminary numbers document only 228 thousand pounds caught in 2010. The Eberhardt School of Business at the University of the Pacific estimates that salmon fishery closures during the drought resulted in a loss of 1,823 jobs and $118.4 million in income compared to the jobs and income of the salmon fishery in 2004 and 2005 (Michael et al. 2010).

In addition, despite statements that significant quantities of water were diverted during the drought to natural ecosystems (Nunes 2009), many of the state's environmental flows went unmet during the drought period. For example, during the 2008 water year (October 2007 – September 2008), flow objectives along the American River were not met for 8 consecutive months (CDEC and AFRP 2001). In the 2009 water year (October 2008 – September 2009), Stanislaus River flows fell under the minimum required for 4.5 consecutive months beginning in November 2008. Over the drought period, average unmet annual flow quantities along the San

Joaquin River were 500 times the level of unmet flows in 2006, and in 2009, flow objectives were not met 67% of the time (CDEC and WQCP 1995). Reduced environmental flows have economic implications, such as impacts on water and riparian land quality. These may be quantified to a degree in terms of "environmental services" provided by natural river flows to both people and the environment. However, there are currently no widespread, accepted methods for quantifying these impacts in economic terms.

Finally, we assess and quantify the impacts of the drought on California's hydropower production, which declined significantly during the drought years. During the three-year drought period, California hydropower was roughly halved. This lost hydropower was made up with the purchase and combustion of additional natural gas. We calculate that electricity rate payers spent $1.7 billion to purchase natural gas over the three-year drought period, emitting an additional 13 million tons of CO_2 (about a 10% increase in total annual CO_2 emissions from California power plants). The substitution of hydropower with natural gas also released substantial quantities of nitrous oxides, volatile organic compounds, and particulates – pollutants that are known contributors to the formation of smog and triggers for asthma.

There are several main conclusions of this assessment. Although agricultural revenues remained high during the drought, some of the response strategies such as groundwater mining were short-term fixes that would not provide water security in the face of a longer or more severe drought. Aquatic ecosystems have suffered long-term declines and have little resiliency to changing conditions. And our energy sector currently has limited ability to produce or buy renewable energy sources to replace hydropower production during droughts. In order for California to become more resilient to future drought conditions, it will be critical to shift from crisis-driven responses to development and enactment of long-term mitigation measures. All of the sectors that we examine in this report (agriculture, energy, and the environment) are highly vulnerable to future droughts and should develop more comprehensive drought planning and mitigation measures to reduce the potential for human, environmental, and economic harm.

Impacts of the California Drought from 2007 to 2009

Introduction

Over a decade ago, the Pacific Institute published two reports on the costs associated with California's drought from 1987 to 1992. These reports provided a comprehensive assessment of the consequences of the second driest period in California's recorded climate history. This report looks back on the most recent drought-period, evaluating its impact on California's economy and environment. From 2007 to 2009, precipitation was 25% below the long-term average, while stream flow was 40% below average (DWR 2010). Many residents found themselves subject to voluntary or mandatory restrictions on water use and some farmers saw their surface water supplies curtailed.

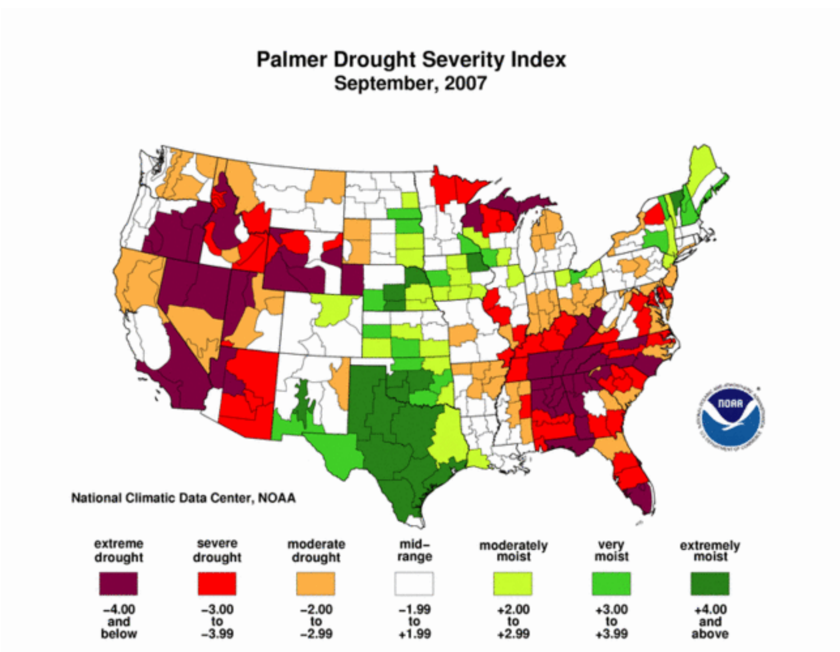
Considerable controversy has arisen throughout California, and even the nation, over the impacts of the most recent drought. Here, we present the information on impacts and, where possible, economic costs of the drought for our economy and environment. We also assess what this recent drought tells us about California's vulnerability to future droughts. We do not provide an overall "dollar" estimate of the costs of the drought to California, in part because insufficient data are available, especially on hard-to-quantify impacts to ecosystems. As a result, such estimates can be misleading because they focus on those impacts that can be easily quantified while undervaluing those impacts that cannot be readily assessed in economic terms. Indeed, our study suggests that many of the most severe impacts of the 2007-2009 drought were in those sectors that are not adequately evaluated by economic measures.

The impacts of drought on any one sector are also extremely difficult to differentiate from other, non-drought-related changes. For instance, agricultural production in any given year is affected by the global economy; climate variables (e.g., temperature); natural disturbances (e.g., pests); shifting market prices; changing subsidies and incentive programs; decisions made in previous years; and longer term financial conditions in the farm sector. Similarly, difficulties exist in trying to assess the impacts of the drought on the natural environment. Ecosystems are not static, but dynamic. Over any period of years they are affected by many anthropogenic and natural forces, drought being just one. Among the natural forces that affect ecosystems are variations in climate, ecological succession, and natural catastrophes. Among the anthropogenic factors influencing ecosystems are changes in population, land use, water use, pollution, and the introduction of exotic species.

Yet despite these difficulties, there is a growing need to understand the scope and magnitude of drought impacts on the state's economy and natural resources. The state's rising population, declining ecosystems, and climate change all contribute to growing pressure on water resources. It will be increasingly important to have robust and resilient strategies to cope with drought statewide. The recent drought provides a unique opportunity to retrospectively examine how the drought affected various sectors, and how those sectors responded. This information can help to improve drought planning and, ultimately, to minimize negative consequences of future droughts.

The Water Situation: 2007-2009

No simple, concise definition of drought exists (Cooley et al. 2008). In general, a drought is a hydrological extreme caused by a persistent and abnormal moisture deficiency. There are many ways of measuring drought, including soil-moisture levels, total precipitation, volume of streamflow or runoff, and quantity of water stored in reservoirs. One standard index used to measure drought in the United States is the National Oceanic and Atmospheric Administration's Palmer Drought Severity Index (NOAA 2011), which measures soil moisture nationwide (Figure 1). At the end of the 2007 water year, Northern California was classified as experiencing moderate drought conditions, while Southern California was classified as experiencing extreme drought conditions. By the end of the 2008 water year, almost all of California was classified as experiencing severe drought. And at the end of the 2009 water year, only Southern California was experiencing extreme or severe drought conditions.



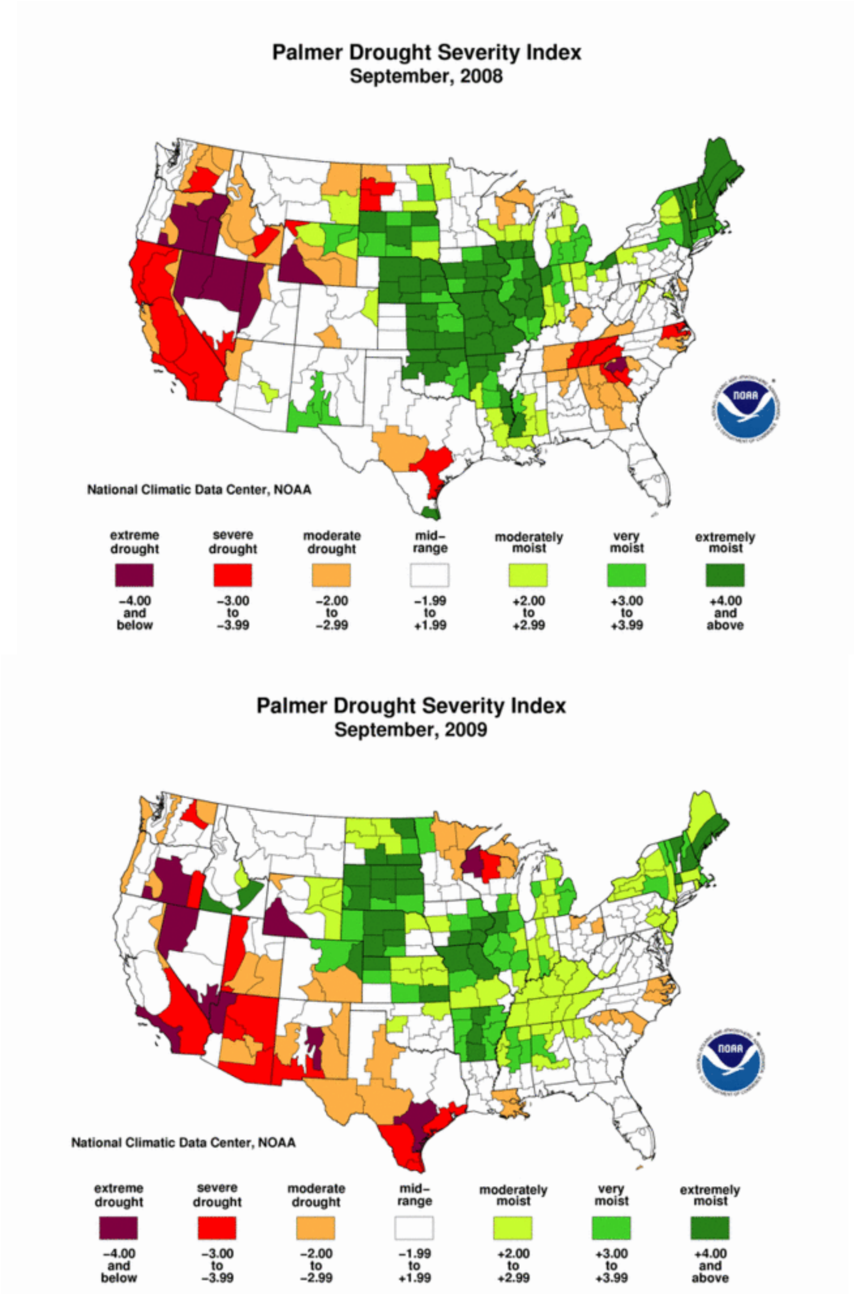


Figure 1. Palmer Drought Severity Index, September 2007, 2008, and 2009
Source: NOAA 2011

According to the California Department of Water Resources (DWR), water years 2007-2009 were the 12th driest three-year period in recorded climatic history (DWR 2010). Droughts in the late 1920s, 1970s, and 1980s were more severe in terms of the state's hydrology (see Table 1) (DWR 2010). Impacts of the drought were particularly apparent in the Sacramento and San Joaquin River basins, an area that spans the Central Valley of California and drains the snowpack of the Sierra Nevada Mountains. During the drought years, depths of groundwater, surface water, and snowpack storage in the Sacramento- San Joaquin basin were lower overall than in previous years (Famiglietti et al. 2011) (See Figure 2). The impact of the recent drought on the state's hydrology and water storage has been assessed by both the Congressional Research Service (Cody et al. 2009) and the DWR (2010). We summarize their findings here.

Table 1. Drought severity in the Sacramento and San Joaquin Valleys (adapted from DWR 2010)

Drought Period	Sacramento Valley Runoff		San Joaquin Valley Runoff	
	*MAF/year	% of average 1901-2009	*MAF/year	% average 1901-2009
1929-1934	9.8	56%	3.3	56%
1976-1977	6.6	38%	1.5	26%
1987-1992	10.2	58%	No data	No data
2007-2009	11.2	64%	3.7	63%

*million acre feet

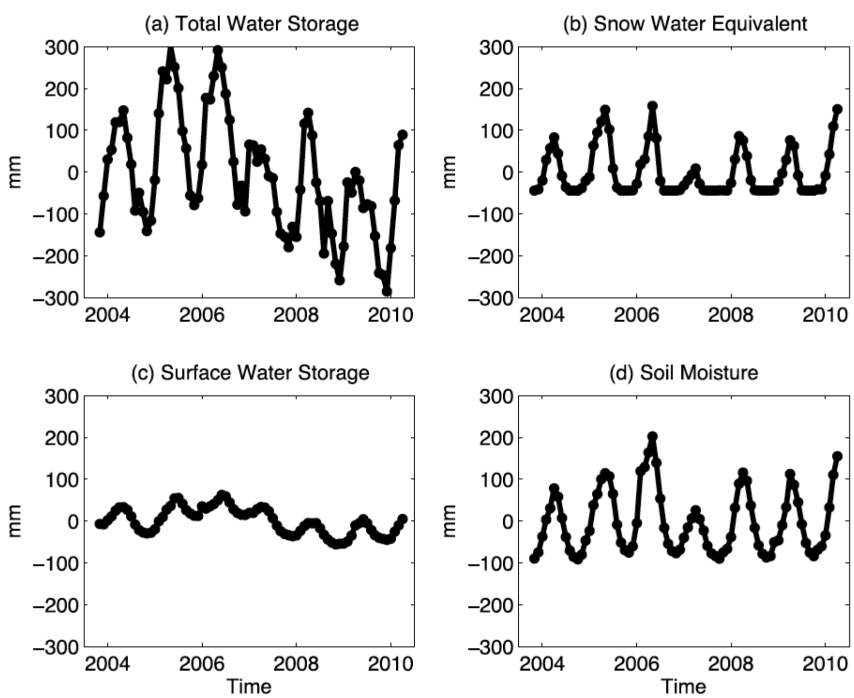


Figure 2. Depth (mm) changes in Sacramento-San Joaquin River Basins in a) total water storage; b) snowpack water equivalent; c) surface water storage, and d) water in soil moisture
Source: Famiglietti et al. 2011

Precipitation

During the 2007-2009 drought, precipitation statewide ranged from 64% of average in 2007 to 82% of average in 2009 (DWR 2010). While comparing drought year precipitation to the average is useful to differentiate drier from wetter years overall, California's annual rainfall is highly variable, across both time and space. California is geographically and climatically diverse; dominated by a Mediterranean climate, characterized by extreme inter- and intra-annual variability in precipitation.

In 2007, the first and most severe year of the drought, California's North Coast received 81% of average rainfall, while the southeastern desert received 14% of average (DWR 2010). During the three drought years, the Sacramento River Basin, which supplies water to the northern Central Valley, received 69%-87% of average precipitation; the San Joaquin Basin, supplying the southern Central Valley, received 64%-89% (DWR 2010). In the hardest hit central and southern coast regions, water users received only 50% and 31% of average in 2007, respectively (DWR 2010). The state received similarly reduced levels of rainfall (averaged across the state) during the last major drought: between 61% and 86% of average statewide during the 1987-1991 drought years (DWR 1991 as cited in Gleick and Nash 1991).

Runoff

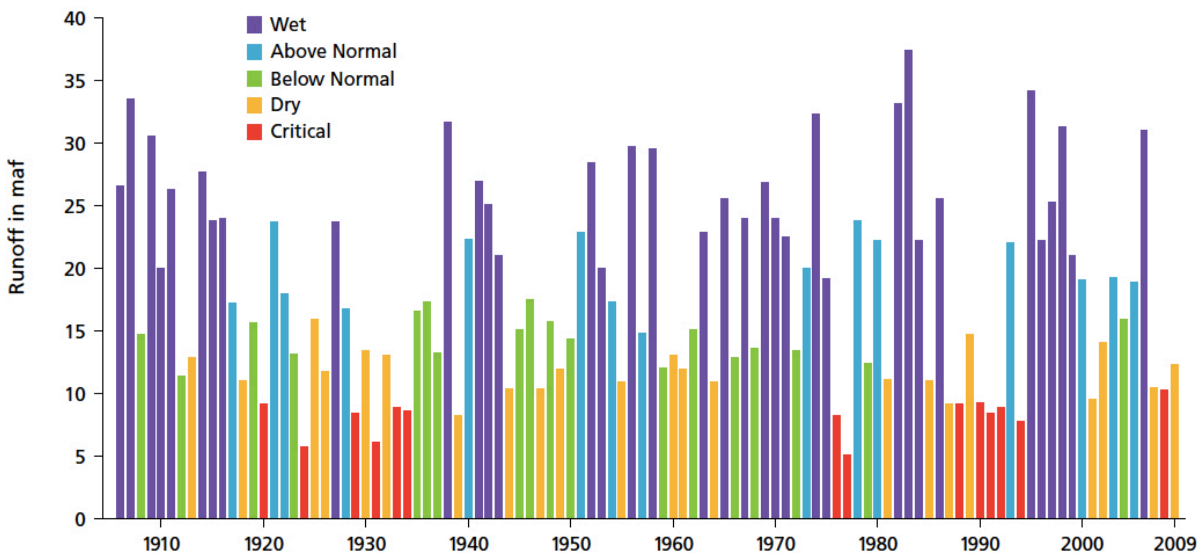
Surface runoff is the water flow that occurs when the rate of rainfall exceeds the rate at which water can infiltrate into soils or when soils are saturated and excess water flows over the land. This is a major component of the water cycle. Runoff can be used immediately; diverted into storage reservoirs; or drain to the ocean. During the drought years, statewide runoff was 53% of average in 2007 and 65% of average in 2009, compared to 173% of average in the wet water year of 2006 (DWR 2010).

Runoff in the Sacramento Valley was 64% of the average during the recent drought; however, runoff was lower in past droughts, down to 38% of average in the 1976-1977 drought. By the end of 2009, reservoir levels were at 72% of average statewide with particularly low storage in the Klamath River Basin, Lake Shasta, Lake Oroville, and San Luis Reservoir. By the end of the 2007-2009 drought, state reservoirs were filled to 72% of average, while reservoir levels near the end of the previous major drought were at 65% of average (DWR 1991b as cited in Gleick and Nash 1991). For a more detailed description of reservoir storage levels see DWR 2010.

As with precipitation, fluctuations in seasonal and annual runoff are the norm in California. There is no true, consistent "normal" runoff amount for California, although calculations based on historical records and forecasts employed by DWR and the State Water Resources Control Board (SWRCB) serve this purpose in the long term.[3] Both agencies characterize water supply in terms of water year categories originally created by the SWRCB as part of their regulatory responsibilities, defined as: wet, above-normal, below-normal, dry, and critically dry water

[3] The use of historical records is a potential source of error, as that record is not necessarily a reliable guide to the true range of what might occur in California in the future, even if there were a stable climate.

years. These categories serve as indicators of conditions in the chief water-supplying watersheds of the state – those draining the western slope of the Sierra Nevada Mountains, the Sacramento and San Joaquin Rivers, and their tributaries (DWR 2010). In the San Joaquin hydrologic region, 2007 and 2008 were critically dry years, and 2009 was a below-normal year; in the Sacramento watershed, 2007 and 2009 were dry, and 2008 critically dry (Figures 3 and 4).



The Sacramento Four Rivers are: Sacramento River above Bend Bridge, near Red Bluff; Feather River inflow to Oroville; Yuba River at Smartville; American River inflow to Folsom

Figure 3. Sacramento Four Rivers unimpaired runoff
Source: DWR 2010

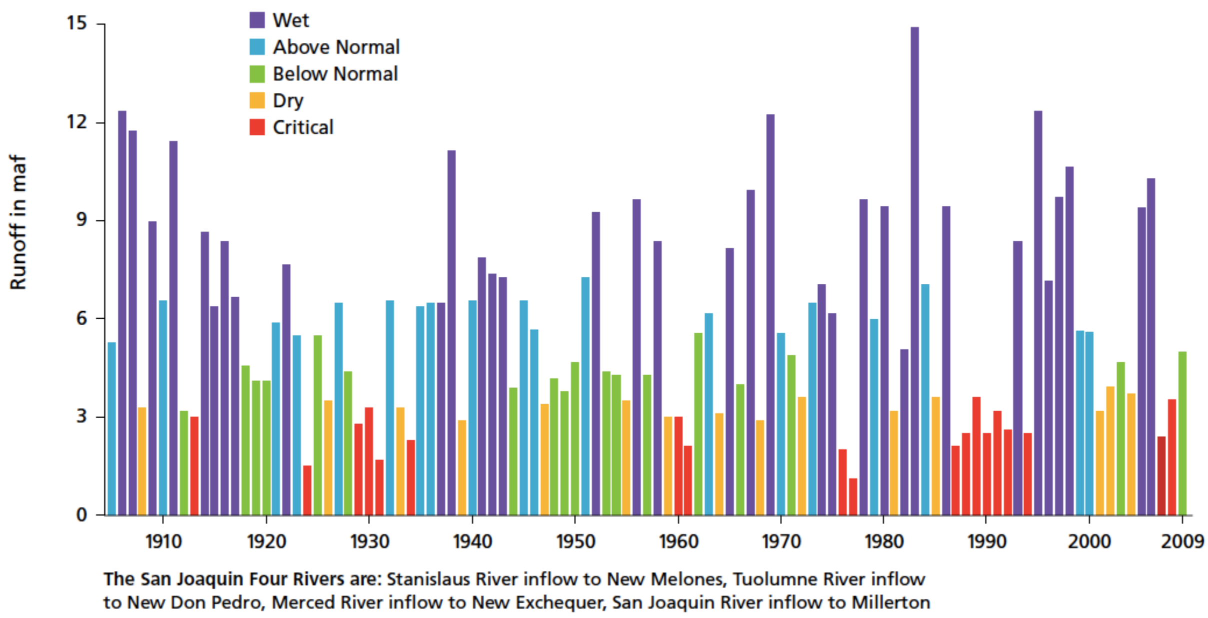


Figure 4. San Joaquin Four Rivers unimpaired runoff
Source: DWR 2010

This is not the first time California has seen "critically dry" conditions in the state. Past droughts have been both more severe (1977-1978) and longer in duration (1987-1992). However, a statewide "drought emergency" was declared in 2007-2009.

Groundwater

During droughts, groundwater is affected in a variety of ways, primarily in that there is less precipitation and runoff to naturally recharge groundwater and there is often a shift from the use of surface water to groundwater as surface water supplies become scarce. Groundwater pumping in California is largely unregulated, except in adjudicated basins.[4] California's water code, written at the turn of the century, uses unscientific language to divide the state's approach to managing surface water and "subterranean streams" (which are regulated) from groundwater (which is not regulated). Noted legal scholar Joseph Sax wrote an important report on this distinction (Sax 2002), concluding that the SWRCB has authority over groundwater when extraction has an impact on surface water (under the Water Code Section 1200), and when the extraction might have an adverse impact on instream values (under the public trust doctrine and the waste and unreasonable use doctrine). The report was pilloried by powerful water users, and the Board agreed not to adopt its conclusions. The result of the continuation of the state's

[4] Adjudication is a legal process in which a court reviews contested water rights and makes a formal judgment or decision about the disputed matter.

bifurcated approach to managing interconnected surface and groundwater resources can be seen most plainly in the ongoing overdraft of many groundwater basins.

Measuring groundwater depletion in California is difficult due to a lack of monitoring infrastructure in many areas and political opposition to monitoring efforts by some groundwater users. Due to the intense opposition to monitoring groundwater extraction by individual users, recent efforts have focused on using remote-sensing to track groundwater levels over time (Famiglietti et al. 2011, USGS 2009). These data show drought period declines in the water volume of San Joaquin and Sacramento River Basins (surface water and groundwater combined), and long-term declines in the volume of water present in the basin's underground aquifers.

GRACE, the Gravity Recovery and Climate Experiment, launched twin satellites in March 2002 to make detailed measurements of the Earth's gravity field. One of the important applications of this technology is tracking the movement of water around the globe, particularly groundwater. The amount of water flowing through a given river basin (such California's Sacramento and San Joaquin River Basins) varies from month to month and can be monitored from space by looking at how it alters the Earth's gravitational field. Results from the first few years of GRACE data have already delivered stark news about the status of groundwater resources worldwide: underground aquifers that may have taken thousands of years to fill are being drained much faster than they can be replenished by rainfall or river runoff, called overdraft.

The groundwater basins that underlie the Central Valley contain one-fifth of all groundwater pumped in the nation and are, in effect, California's largest reservoirs. In 2009, the United States Geological Survey (USGS) released a long-term analysis of groundwater levels in the Central Valley based on GRACE data. Among the study's major findings were significant declines in groundwater levels over the last forty years (Faunt 2009). These declines have been primarily driven by the overdraft of the Tulare Basin, in the southern portion of the San Joaquin Valley. Between 1962 and 2003, an average of 9.1 million acre-feet of water went into storage annually, and an average of 10.5 million acre-feet were removed annually (Faunt 2009). Thus, in typical years the net loss in groundwater storage was about 1.4 million acre-feet. Groundwater overdraft is particularly severe during dry periods, when the data show that not only the Tulare Basin but also the Sacramento Valley and San Joaquin Basin pump more groundwater than is replenished.

A more recent study (Famiglietti et al. 2011) finds that groundwater levels in the San Joaquin Valley dropped 2-to-6 feet per year from October 2003 – March 2009 while groundwater levels in the Sacramento Valley dropped a less extreme 0.3 to 0.5 feet per year over that same time period (see Figure 5). Overall, the Sacramento-San Joaquin River Basin lost approximately 25 million acre-feet over the time period – roughly the capacity of Lake Mead, the largest reservoir in the U.S. (Famiglietti et al. 2011). In addition, during the drought years, groundwater storage declined by over 29 million acre-feet (Famiglietti et al. 2011). Therefore, the reduction in the volume of total groundwater during the drought was 48 times greater than pre-drought reductions over same number of years.

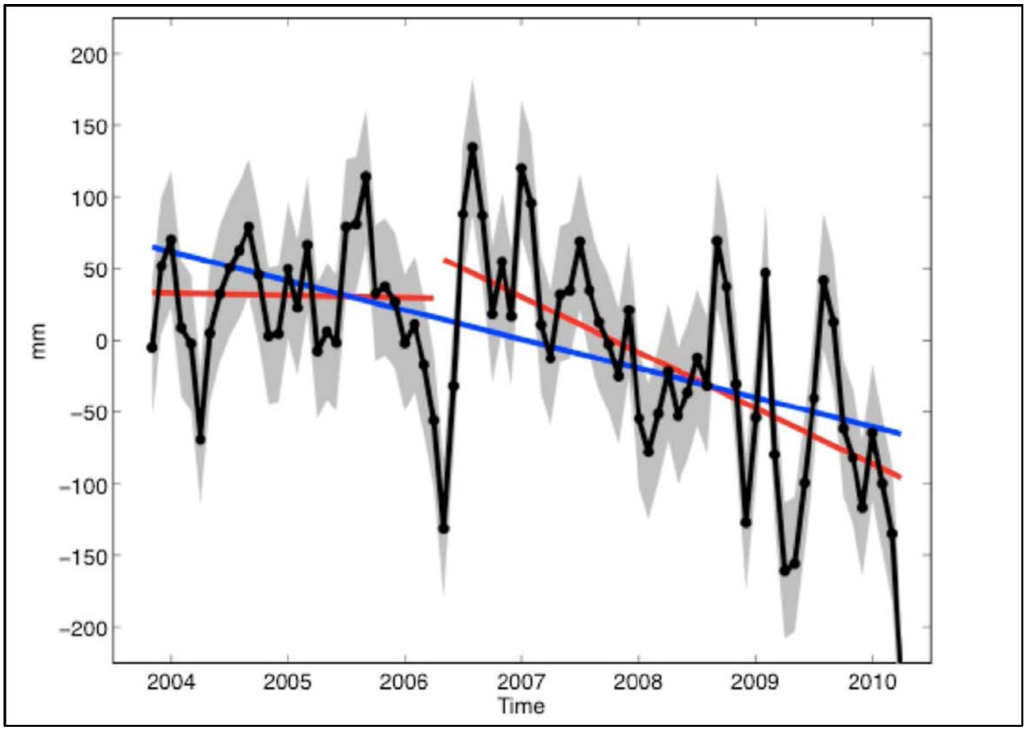


Figure 5. Groundwater storage depth (mm) changes in the Sacramento-San Joaquin River Basins, 2003-2010
Source: Famiglietti et al. 2011

Note: Red lines indicate separate October 2003 – March 2006 (pre-drought) and April 2006 – March 2010 (drought period) trends in groundwater storage; the blue line is the overall trend in groundwater storage from October 2003 – March 2010; gray shading indicates monthly errors.

Impacts to Federal and State Water Project Deliveries

Water supplies in California come from a combination of snowpack, precipitation, runoff, and groundwater. California has developed its seasonally- and geographically-limited freshwater supply over the past century through intensive infrastructure development. Dams and reservoirs, surface and groundwater pumps, and hundreds of miles of artificial canals store and deliver water where there was originally none, and more reliably and dependably than would otherwise be possible. While natural precipitation and streams supply some of the state's agriculture (such as in the wetter northern and coastal areas), the majority of irrigated agriculture is located in the Central Valley, a long flat valley stretching down the center of the state between the eastern Sierra Nevada and coastal mountain ranges.

The State Water Project (SWP) and the Central Valley Project (CVP) include massive storage reservoirs north and south of the Delta and pumps and aqueducts that move water from the southern part of the Delta to users in the Central Valley and urban centers of southern California (see Figure 6). The SWP is operated and managed by DWR. DWR delivers SWP water for agricultural, municipal, industrial, environmental, and recreational needs based on a mix of hydrologic conditions, reservoir storage, and requests from contracting agencies. The SWP was built in the 1960s-70s; exports for agriculture increased rapidly through the 1970s, remained steady between the mid-1980s and 2000, and have declined since 2000 (as municipal and industrial uses have increased). The CVP, authorized by the federal government in the late 1930s, but constructed throughout subsequent decades, is operated by the Bureau of Reclamation and delivers on average 7 million acre-feet of water a year – or about 20% of all water used in California – to 250 project contractors. The CVP primarily provides water to irrigate farms in the Central Valley, supplying more than 6,800 individual farms (EWG 2004).The drought's impact to these state and federal water projects, and users, is described below.

Figure 6. State, federal, and local water projects in California
Source: DWR 2010

Since exports of Delta water commenced in 1956, total exports have increased steadily, with short-term reductions during drought periods, e.g., 1977-78, 1989-1992, 2007-2009 (Figure 7). Yet, project contractors (or those that receive Delta water from water projects) may not receive 100% of their contractual allocations even in normal years. This is due to the fact that the federal and state water projects were never fully completed and contractual allocations were larger than actual resource availability could guarantee. For instance, the Auburn Dam was originally authorized as part of the CVP but construction was halted in the 1970s due to rising concerns regarding the seismic instability of the site, its cost, and its environmental impacts. Recently, the SWRCB voted unanimously to revoke the water rights it granted over 30 years ago to the Bureau of Reclamation to store water behind the Auburn Dam. In addition, the initial proposal to build a Peripheral Canal as part of the SWP was defeated in a statewide referendum in 1982.[5] Thus, the federal and state projects have promised more water than they can deliver in most years.

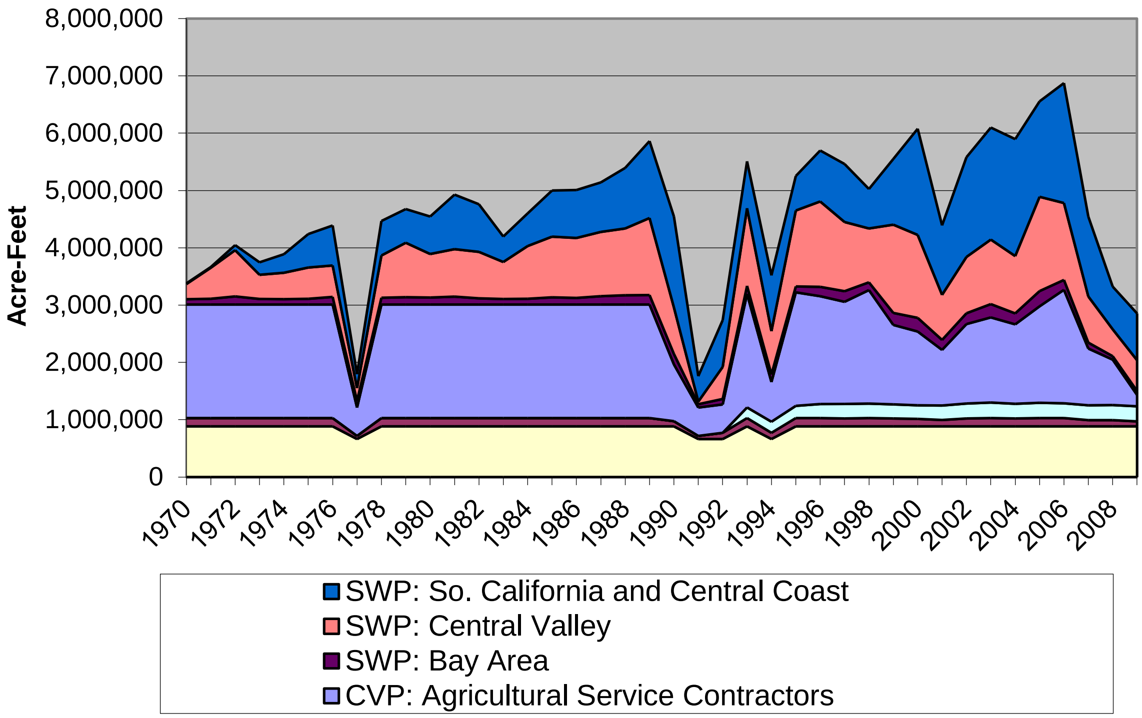


Figure 7. Estimated distribution of federal and state water deliveries (1970-2009)
Source: Rosekrans 2011

In situations of shortage there is also a hierarchy of contracts whereby some contractors receive more of their contract water than others, leading to highly varied drought impacts. In the case of the SWP, the project supplied 100% of contractual amounts to all contractors in 2006, but only 60% in 2007, 35% in 2008, and 40% in 2009 (DWR-SWPAO 2000-2006, DWR-SWPAO 2010). However, reductions in CVP water allocations were more complex due to historic agreements

[5] The peripheral canal is a proposed canal or pipeline that would divert water from the Sacramento River around (or under) the Sacramento-San Joaquin River Delta directly to pumping stations, where water is pumped south to Central and Southern California water users.

with the Bureau of Reclamation. Put simply, some farmers (e.g., the Exchange Contractors in the San Joaquin Valley and the Sacramento River Settlement Contractors) made a deal with the Bureau of Reclamation exchanging their riparian water rights for project water on the condition that the Bureau supply these priority contractors with water before delivering water to other contractors (see Sidebar 1). Thus, even in a drought, these priority contractors often still receive full contract water amounts while lower priority contractors bear the brunt of water cuts.

It is important to note that water supply contracts to specified quantities of state and federal project water (administered by the DWR and USBR, respectively) are different than surface water rights (administered by the SWRCB). This discussion refers to contract water supplied via the CVP and SWP. In the wet water year of 2006, all CVP contractors received 100% of contract quantities. During the drought years, only priority contractors (exchange and settlement contractors and Class I Friant Division contractors) received 100% of their maximum contract quantities of water, while other contractors (both urban and agricultural), and particularly those South-of-Delta, received less than full contract amounts – often much less.

Sidebar 1: Agricultural Coping Strategies

The agriculture community employed a variety of coping strategies to sustain agricultural revenue and production, despite water supply cutbacks. In general, coping strategies included investments in water saving practices, switching to less water intensive and/or higher value crops, fallowing land, water banking and water transfer arrangements, and an increase in groundwater use. Responses varied from one agricultural region to the next and from farm to farm. Original estimates of potential job and income losses in the agricultural sector due to the drought were revised to be much lower, in part, due to this combination of coping strategies (Michael et al. 2010).

Statewide, there has been a steady increase in fruit and nut acreage and a decrease in field and seed crop acreage over the past decade. Water availability along with economic factors (e.g., crop prices) certainly play a role in driving transitions from field and seed to fruit and nut production in the short and long term. Michael et al. (2010) found that the San Joaquin Valley fallowed roughly 256,000 acres in 2009, but that virtually the entire decline in net harvested acreage was in field and seed crops as farmers prioritized higher value fruit and nut crops. Similar trends were apparent to varying degrees at the water district, county, and state scales.

Fallowing occurred primarily in areas with reduced water deliveries from state and federal projects: Fresno, Kern, and Kings Counties (Michael et al. 2010). Overall, Central Valley regions, particularly on the west side of the San Joaquin Valley, fallowed significant acreage, while those in other parts of the state with more reliable water supplies did not. Fallowing during the drought was typically limited to field crops (as we see in our county and water district level analysis) and, in some cases, led to water sales and transfers. According to UC Santa Barbara's Water Transfer Database and the USBR, between 500,000 and 800,000 AF of water were transferred for agricultural use in 2009 (Michael et al. 2010). Water transfers were important to reducing negative impacts of water shortages (Michael et al. 2010).

Finally, groundwater use increased during the drought. However, it is important to distinguish between increased groundwater mining and increased conjunctive use. "Groundwater mining" refers to relatively unregulated groundwater pumping that draws down aquifers without replenishing them, while "conjunctive use" involves pumping groundwater in dry periods, but then recharging groundwater reserves when surface water is available. Conjunctive use requires certain physical characteristics in terms of the groundwater basin, surface water availability, and access to delivery infrastructure (see Christian-Smith et al. 2010). In addition, conjunctive management requires institutional infrastructure including agreements, monitoring, and accounting methods to guarantee access to stored water.

In 2008 and 2009, Delta exports were about 40% less than average state and federal Delta exports over the last decade (see Table 2).

Such decreases always occur during droughts and when compared to prior droughts, these export reductions were not particularly severe. In 1991 and 1992, the final years of the last major drought, CVP and SWP exports totaled 3.3 MAF and 3.0 MAF, respectively (USBR-MP 2008). In comparison, 2008 and 2009 exports were around 3.5 MAF/year, exporting 200,000 -500,000 acre-feet more than during the final years of the last major drought (see Table 3).

Table 2. Comparison of senior and junior CVP contract holders' annual water supply allocations as the percentage of maximum contract quantities received

CVP Contractor	2006 (Wet)	2007 (Dry)	2008 (Critical)	2009 (Dry)
San Joaquin Exchange and Sacramento River Settlement Contractors	100	100	100	100
Friant Division				
Class I	100	65	100	100
Class II	100	0	5	18
Other Contractors				
North-of-Delta Ag	100	100	40	40
North-of-Delta Urban	100	100	75	75
South-of-Delta Ag	100	50	40	10
South-of-Delta Urban	100	75	40	75

Source: Summary of Water Supply Allocations, Historical, Central Valley Operations Office, Mid-Pacific Region, USBR (USBR-MP 2011a)

Table 3. Federal (CVP) and State (CVP) Project exports from the Delta (in million acre-feet), from the Banks and Jones (Tracy) Pumping Plants, 2000-2010

Water Year	CVP Exports	SWP Exports	Total CVP and SWP Exports	% of 10-Yr Avg Annual Exports (1998-2007)	% of 3-Yr Avg Annual Exports (2004-2006)
2000	2.83	3.45	6.28	110%	101%
2001	2.65	2.38	5.03	88%	81%
2002	2.75	2.70	5.45	96%	88%
2003	2.86	3.39	6.25	110%	101%
2004	2.93	3.14	6.07	106%	98%
2005	2.83	3.58	6.41	112%	103%
2006	2.74	3.50	6.24	109%	101%
2007	2.90	2.82	5.72	100%	92%
2008	2.02	1.48	3.50	61%	56%
2009	1.99	1.49	3.47	61%	56%
2010	2.20	2.39	4.59	80%	74%

Source: For years 2000-2007: USBR, Mid-Pacific Region, Central Valley Operations (CVO) Office Database, 2011 (summarized in the USBR CVO Operations Criteria and Plan Biological Assessment (OCAP BA) 2008). For years 2008-2010: DWR database exports provided by DWR Water Delivery Analysis and Documentation Branch, State Water Project Analysis Office 2010. (USBR-MP 2008, USBR-MP 2011b, DWR-SWPAO 2010)

Note: The 10-year average represents a lower approximation of recent average annual Delta exports of 5.7 MAF/year; the 3-year average represents a higher approximate average of 6.2 MAF/year. The 10-year average includes the full range of wet, normal, and dry years, while the 3-year average only includes normal and wet years.

The Role of Regulation

While the hydrologic drought reduced water availability, regulatory restrictions on water pumped south of the Delta further contributed to the water shortage (Cody et al. 2009). The debate was reported as "farms vs. fish" but the actual role of regulation in affecting water supplies was far more complex. Several pieces of federal and state environmental legislation affect Delta pumping by providing a network of protections for human and environmental health. In 2009, the final year of the drought, Delta exports were reduced by about 40% (USDOI 2009). DWR reports that three-quarters of the reductions in Delta exports (1.6 MAF) were due to drought conditions and that less than a quarter (0.5 MAF) was due to environmental protections such as maintaining Delta salinity standards (DWR 2010).

Quantifying the relative impact of these reductions in a historical context is difficult, as one must establish a baseline for annual Delta exports. The Congressional Research Service (Cody et al. 2009) calculates this three different ways, using 3-, 5-, and 10-year averages to demonstrate how the use of different time periods for average annual Delta exports yields different results for the percentage of Delta export reductions in 2009. The Congressional Research Service reports that when using a 3-year average as the baseline, rather than a 10-year average, only 19% (the same 0.5 MAF) of the total reduction in Delta exports can be attributed to endangered species protections (Cody et al. 2009).

Although the Endangered Species Act (ESA), and Judge Wanger's ruling that required reduced pumping in order to protect endangered fish (see Sidebar 2), has been pointed to as the cause of reduced water deliveries, there are actually a variety of water quality and statutory obligations that contributed to restricting Delta exports. The Congressional Research Service concluded that even if one piece of environmental legislation were waived or overridden (e.g., the ESA), federal and state agencies would still be required to comply with other state and federal laws and directives that protect the environment, including the federal Clean Water Act, the state Porter-Cologne Act and its implementing directive D-1641, the California Endangered Species Act, the California Fish and Game Code, and the Central Valley Project Improvement Act (Cody et al. 2009).

The history of these obligations pre-dates the ESA. Delta salinity standards, for example, arise from the original water rights provided by the State of California (via the SWRCB) to the CVP and SWP to divert water upstream of the Delta, thereby raising the salinity of water used by in-Delta users. The conflict between upstream diverters and water quality for in-Delta water users has been the subject of litigation in California for much of the past century (Hundley 2001). Hanemann and Dyckman (2009) argue that the state has failed to adequately manage intense conflicts between groups of Delta system stakeholders with opposing interests. The drought issues serve as an expression of the nature of this extreme conflict, and its problematic, unresolved status.

Sidebar 2: Recent Environmental Litigation and Court Decisions to Protect Flow for Endangered Fish Species Biological Opinions

Under the Endangered Species Act, it is illegal for federal agencies to authorize or carry out any action that will further jeopardize a species listed as threatened or endangered (FWS n.d.). Therefore, the Fish and Wildlife Service must provide documentation, commonly in the form of a "biological opinion," showing that their operations will not jeopardize listed species. In 2008 and 2009, the USBR and the DWR issued biological opinions concerning the effects of the operations of the CVP and SWP. The 2008 USFWS' biological opinion provides actions to protect the listed Delta smelt; the NMFS's 2009 Biological and Conference Opinion provides actions to protect listed Chinook salmon, steelhead, and sturgeon. Both the USFWS Opinion and the NMFS Opinion are the subject of ongoing litigation in federal court, with claims from environmental groups under the ESA and NEPA seeking better species protection, and counter-claims from water users such as Westlands Water District and the San Luis Delta Mendota Water Authority challenging the implementation of protective actions by the federal agencies.

Rulings stemming from these cases gained particular notoriety during the 2007-2009 drought. In 2009, court decisions curtailed Delta pumping in light of ESA restrictions, impacting the amount and timing of deliveries to south-of-Delta users. The DWR provides a chronology of fish related regulatory actions during the drought years (DWR 2010). Here, we focus on individual cases in order to explain these cases' relevance to the discussion of the impact of environmental protections on water supply during the drought. It should be noted that there are numerous environmental regulations that impact water supply. The ESA "biological opinion" cases were particularly contentious, but were not the only cause of restriction to available water supplies in the Central Valley – such as the San Joaquin River restoration program which began in the middle of the drought.

The Delta Smelt Decision

Delta smelt are found only in the Sacramento-San Joaquin estuary, and are considered indicators of the estuary's overall ecological health. In 1993, they were listed as threatened under both the California state and federal Endangered Species Acts. In 2005, a biological opinion regarding the impacts of CVP and SWP operations on Delta smelt found that increased pumping would not negatively impact the fish. Based on this information, the Bureau of Reclamation and the California Department of Water Resources increased pumping from the Delta. Delta smelt population continued to decline and in 2005, the fish count was only 2.4% of that in 1993 (NRDC 2007b).

A coalition of conservation groups sued the Fish and Wildlife Service (FWS) over the scientific validity of the biological opinion. In May of 2007, Judge Wanger ruled that the biological opinion did not use best available science nor did it adequately consider the impacts of the project operations on critical smelt habitat (Natural Resources Defense Council v. Kempthorne, E.D.Cal., 2007). (continued)

(Sidebar 2 continued)

The USBR began operating under the new conditions, and because those conditions resulted in the reduction of south of Delta water deliveries, state and federal water contractors filed six lawsuits against USFWS and USBR claiming the new project operating conditions illegally restricted diversions; (these lawsuits are consolidated and referred to as the "Consolidated Smelt Cases" (Consolidated Smelt Cases, E.D. Cal., 2009.) In December 2007, U.S. District Judge Wanger provided interim management policies for the Delta, with new operational constraints on the SWP and CVP including increased monitoring of the Delta smelt and decreased pumping from the Delta pending completion of a new biological opinion. On December 15, 2008, the FWS issued a new biological opinion that proposed alternative operational restrictions for the projects.

In November 2009, Judge Wanger ruled that USBR must first conduct an environmental review under NEPA before implementing a biological opinion that called for significant water reductions, and in December, 2010, Judge Wanger remanded the biological opinion to the FWS. Because the Court did acknowledge some negative impacts on Delta smelt from export pumping in its 2010 decision, the extent to which water project operations will be affected in the interim until the FWS issues a new biological opinion is unclear. However, as of February, 2011, parties to the litigation struck a temporary settlement agreement, giving the FWS more time to investigate possible solutions, meanwhile allowing for increased Delta pumping and exports during the first half of 2011.

Pending Decision on Salmonids in the Sacramento River

A similar lawsuit was filed in the same federal court 2004 that challenged a separate biological opinion issued by the Fish and Wildlife Service regarding the impacts of water project operations on endangered winter-run Chinook salmon, threatened spring-run Chinook salmon, and threatened steelhead in the Sacramento River. Like the Delta smelt biological opinion, the FWS provided documentation that project operations would not jeopardize these salmon and steelhead species. In April of 2008, Judge Wanger invalidated this biological opinion as well, bringing water withdrawals north of the Delta under scrutiny. On June 2, 2009, NMFS issued a new biological opinion. Similarly, this spurred the filing of six individual lawsuits in 2009 against NMFS and USBR that challenged the new opinion; again, these cases were consolidated and are referred to as the "Consolidated Salmon Cases" (Consolidated Salmon Cases, E.D. Cal., 2009). A ruling has not yet been issued in this case.

Future Litigation

Decisions made by Judge Wanger in mid-2010 in both the smelt and salmon cases temporarily suspended pumping restrictions, making more water temporarily available for irrigation in the Central Valley. Judge Wanger's decision in this matter highlights the Court's willingness to consider socio-economic impacts alongside environmental impacts. Many perceived the 2010 ruling to be a victory to water users who sought to increase Delta pumping levels by challenging the science of underlying claims that project operations harm fish. While different aspects of those scientific underpinning were alternately questioned and reaffirmed by Wanger's subsequent ruling in the smelt decision (December, 2010), given the contentious nature of Delta pumping operations and ongoing environmental concerns, it is unlikely that litigation concerning the status of biological opinions for the delta smelt, salmon, and other threatened and endangered species will end soon. Because the validity of the biological opinions will likely continue to be debated into the future, this creates an unfortunate uncertainty about implementation of protective actions for fish by agencies tasked with species protection.

Impacts to the Agricultural Sector

Agriculture is a key part of California's history and economy. California's agricultural sector responds to periodic droughts in a number of ways, including shifting to groundwater, changing crops, improving irrigation practices, fallowing land, and engaging in water transfers (see Sidebar 1). Some of these practices, such as fallowing, may reduce California's agricultural revenue from what it might have been if full water supplies had been available. And other responses, such as shifting to higher-value crops, may increase California's agricultural revenue. Responses vary tremendously based on location, water rights and contracts, climate, soils, and other factors. As a result, some counties and communities experienced very little economic disruption while others were severely affected. Overall, the agricultural sector showed great resilience. During the 2007-2009 drought, several crops saw record annual levels of production, such as almonds, tomatoes, and lettuce, and the total value of California's agricultural products combined broke all pre-drought records in each year of the drought (USDA Ag Statistics Report 2009). The resilience of the agricultural sector was the result of several factors, including the sector's strong financial position before the drought began and the variety of response strategies employed (see Sidebar 3). These strategies buffered the state agricultural sector from extreme drought-period losses in acreage, yield, and revenue, and contributed to a far lower number of job losses than originally projected (Michael et al. 2010).

Here, we analyze drought impacts to agriculture at the state, regional, and local levels by looking at the most updated data available, including the County Crop Reports from county agricultural commissioners' offices; the USDA National Agricultural Statistics Service data; individual water district crop reports (CVP contractors are required to report this information to the USBR); U.S. Census data; and California Employment Development Department data. We report primarily on the San Joaquin Valley, the southern portion of the Central Valley, as it experienced the most severe reductions in water delivered through state and federal projects.

This analysis reports changes to acreage (harvested cropland); yield (tons of a harvested crop); and gross revenue (the total market value of agricultural products). All values here are reported in 2010 dollars adjusted for inflation using the average annual Consumer Price Index[6] (CPI) as provided by the Bureau of Labor Statistics (unless noted otherwise). The market value of a crop, or "crop production value," is the primary measure that county agricultural commissioners use to report the value of agriculture in their annual crop reports. It should be noted that this measure represents the gross value of agricultural commodities – the tons produced multiplied by their per-unit market value in a given year. We describe crop production values as "gross revenue" for the agricultural sector at the state, county, and water district level. Gross revenues do not reflect net revenue (farm profits or income), and do not include production costs. Thus, if input costs

[6] The CPI represents the most simple and consistent annual inflation adjustment of value for the various sectors, products, and services discussed in this report. We realize that use of other indices provided by the Bureau of Labor Statistics could provide more accurate values for individual sectors. However, we find that this level of precision is unnecessary for this report. Additionally, adjustments using sector-specific price indices would not substantially change the total, annual values published in this report.

have increased, net farm income may decrease even while gross revenue increases. The market value of agricultural products sold also does not include payments farms received for participation in many federal farm programs, such as crop insurance. Data shows that significant funds were dispersed in 2009 to farms in the Central Valley through crop insurance payments.

In the San Joaquin Valley, we find that the drought-impacted agricultural sector maintained much of its production, particularly production of its most valuable crops. Overall, drought impacts are minimal enough as to be very difficult to disentangle from the "normal" fluctuations of agricultural output and economy over the past decade, except in certain local circumstances, which we discuss in our analysis of county- and water-district level impacts. While some analyses focus on the three-year drought period or on 2009 alone (DWR 2010, Michael et al. 2009), we evaluate trends from 2000-2009 for acreage, yield, and revenue from USDA agricultural statistics data, and data from California county agricultural commissioners' reports. This timeframe includes the full drought period, a normal water year, and a wet water year (2000 and 2006, respectively). Additionally, issuance of this report in 2011 allows us to use the most recent, complete, and revised information available from the USDA (such as the 2010 NASS California Agricultural Statistics that aggregate full state agricultural data for 2009); 2009 county crop reports prepared by agricultural commissioners; DWR reports (finalizing 2009 water year data); and the most recent U.S. Census data and California Employment Development Department Data, providing a comprehensive retrospective look at the state's most recent drought.

It is important to emphasize that we do not focus on establishing the causal factors driving record agricultural revenues, or changes in acreage and yields – all are highly complex and often inter-related. Many factors, such as global markets, prices, fires, pests, and disease can cause significant fluctuations in agricultural production patterns. A more in-depth economic analysis, examining the relative contribution of different factors to the changes seen during the drought would be useful, but is beyond the scope of this report.

Statewide

California produces approximately 400 different agricultural commodities, supplying about half of the fresh fruits, vegetables, and nuts consumed by Americans (CDFA 2007). California also provides food for the international market, accounting for 15% of the nation's total agricultural export (Trott 2007). The agricultural sector accounts for an estimated 2% of all jobs in the state. These statewide estimates, however, hide the regional importance of agriculture.

Statewide, the agricultural sector set record highs in production value, or gross revenue, during the 2007-2009 drought (USDA-NASS 2010). According to California's Department of Food and Agriculture (2010), "The state's agricultural sales for 2009 were the third highest recorded, behind only 2008 and 2007." Even in the final year of the drought, 2009, California remained number one in the nation in cash farm receipts (as it has for the past decade) with $34.8 billion in total agricultural revenue, representing 12.3% of the U.S. total agricultural revenue (USDA-NASS 2010).

Here, we compare acreage, yield, and revenue data before and during the drought. We have also performed statistical analyses to estimate the significance of differences between the two periods: pre-drought (2000-2006) and drought (2007-2009). This analysis is limited by the small number of observations. The footnotes list the results from ordinary least squares regressions at a 95% confidence level and potential errors. We provide summaries of statistically significant observations in the text.

The Complex Relationship between Acreage, Yield, and Revenue

Reductions in acreage do not necessarily equate to reductions in yield (tons produced) or value (gross revenue from agriculture). For instance, yield dropped from a decade high of 73 million tons of principle harvested crops in California 2008 to 66 million tons of those crops in 2009. However, even while yield dropped, the gross revenue from agricultural products in the state continued to increase. At the state level, and in the long-term, the relationship between acreage and gross revenue in California is indirect – gross agricultural revenue has been rising as acreage decreases (Figure 8).

This relationship highlights the fact that farm revenue is generated by crop yield (tons of a crop produced), which is determined annually by a variety of factors. Agricultural revenue responds in a complex manner to factors beyond the number of acres planted or tons of crops harvested. Changes in yield, prices, and revenue, are caused by natural factors such as water and weather (temperature), and economic factors such as changes in input costs, demand (consumer) forces that effect crop prices, and external market forces. These factors may come into play individually or in combination – and may be interrelated themselves.

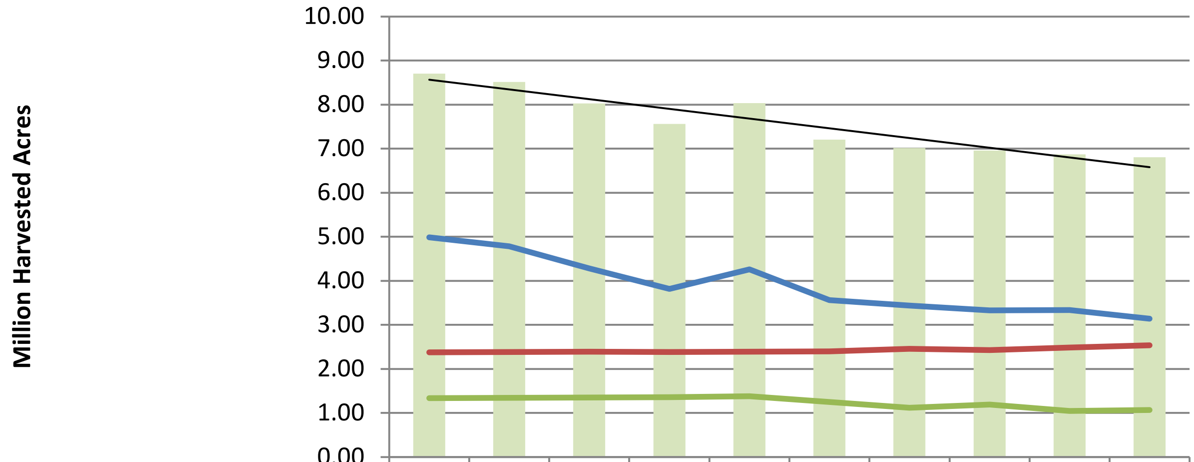
Acreage

Statewide, total harvested crop acreage[7] declined over the course of the drought, but acreage has been in decline for over a decade, even during periods of more abundant water. While the number of acres fluctuates from year to year, there was a statistically significant decline in acreage in California over the past decade.[8] However, the rate of decline actually appears to have slowed during the drought years from 2007-2009. Figure 8 shows that declines in acreage of irrigated crops during the drought were not significantly greater than declines in pre-drought

[7] "Acres" and "acreage" in this report refer to harvested, irrigated acres of farmland unless noted otherwise. Calculations of all crop acres and crop values exclude explicitly non-irrigated rangeland and pasturelands from acreage and production values, unless noted otherwise so as to represent potential water supply impacts to agriculture.

[8] The slope of irrigated acres versus time between 2000-2009 (decade) was determined by ordinary least squares regression (95% confidence level), using annual acreage data. The best-estimate slope for the period is -220,000 ± 27,000 acres per year. Based on this result, there is strong evidence of a decline in irrigated acreage, as indicated by a sample slope significantly less than zero (P-value < .001). Sample slopes for 2000-2006 (pre-drought) and 2007-2009 (drought) were similarly determined. The change in irrigated acres for the 2000-2006 (pre-drought) period is -274 ,000 ± 48,000 acres per year (P-value = .002). The change in irrigated acreage for the 2007-2009 (drought) period is -76,000 ± 7,000 acres per year (P-value = 0.06).

years, nor were drought acreage losses greater than those over the past decade. At the state level, drought-period declines in acreage were smaller than in previous years.



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Total	8.70	8.51	8.02	7.56	8.04	7.21	7.01	6.96	6.87	6.80
Field and Seed Crops	4.99	4.79	4.28	3.81	4.26	3.56	3.44	3.33	3.33	3.14
Fruit and Nut Crops	2.38	2.39	2.39	2.39	2.39	2.40	2.46	2.43	2.49	2.54
Vegetable and Melon Crops	1.33	1.34	1.35	1.36	1.38	1.25	1.12	1.19	1.05	1.07

Figure 8: Harvested acres in California, 2000-2009
Source: USDA NASS California Agricultural Statistics, Crop Years 2000-2009. (USDA-NASS 2000-2009)

Note: Includes field and seed crop, fruit and nut crop, and vegetable and melon crop acreage (excludes nursery and floriculture, and acres devoted to livestock, poultry, and aquaculture). Displayed black trend line is a linear trend of total annual harvested acres.

On a crop type basis, annual decreases in irrigated field and seed crop acres were actually larger prior to the drought. Vegetable and melon crop acreage declined more during the drought than in prior years. However, there was a significant *increase* in fruit and nut crop acreage during the drought.[9]

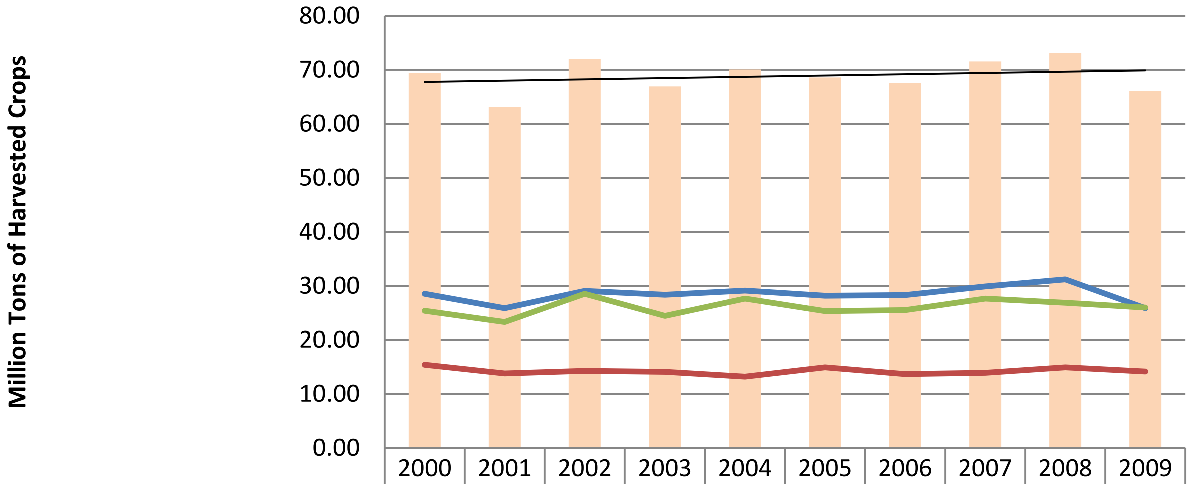
[9] For each crop type, the slope of annual acreage versus time between 2000-2006 (pre-drought) and 2007-2009 (drought) was determined by ordinary least squares regression (95% confidence level), using annual acreage data. For field and seed crops, the best estimate slope between 2000-2006 was -255,000 ± 46,000 acres per year; between 2007-2009 the slope was -96,000 ±57,000 acres per year. For fruit and nut crops, the best estimate slope between 2000-2006 was +10,000 ± 4,000 acres per year; between 2007-2009 the slope was +55,000 ± 3,000 acres per year. For vegetable and melon crops, the best estimate slope between 2000-2006 was -29,000 ± 14,000 acres per year; between 2007-2009 the slope was -64,000 ± 50,000 acres per year.

Yield

Yield fluctuates from year to year, and at the state level does not appear to respond directly to wet or dry water supply years; simply put, in drier years, yields do not necessarily decline. For instance, while 2007 and 2008 were dry years, they are among the decade's highest in terms of yield of irrigated crops statewide. The drought period (2007-2009) saw decreasing annual yields at the state level for field, seed, vegetable, and melon crops, compared to increases in yields of those crops during pre-drought years (2000-2006). On the other hand, fruit and nut crops experienced significant annual increases in yield during the drought period.[10]

In 2009, yields of all crop types dropped from 2008 levels, but production throughout the drought years dropped below 2006 (wet year) levels only once and in a single crop category – in field and seed crops during the final year of the drought (2009). While annual decreases in field and seed crop yield (and to a lesser degree vegetable and melon crop yields) were greater during the drought than in prior years, annual yield of fruit and nut crops remained relatively steady during the drought. Figure 9 shows that yield fluctuates from year to year, and does not appear to respond directly to wet or dry water supply years. For example, drought years 2007 and 2008 were among the highest in terms of crop yield statewide. Overall, the average yield (in tons) for each crop type, as well as the average total combined yield of those same crop types, were higher during the drought period (2007-2009) than prior to the drought (2000-2006).

[10] For each crop type, the slope of annual yield versus time between 2000-2006 (pre-drought) and 2007-2009 (drought) was determined by ordinary least squares regression (95% confidence level), using annual yield data (tons). For field and seed crops, the best estimate slope between 2000-2006 was +143,000 ± 220,000 tons per year; between 2007-2009 the slope was -2,100,000 ± 1,900,000 tons per year. For fruit and nut crops, the best estimate slope between 2000-2006 was -144,000 ± 145,000 tons per year; between 2007-2009 the slope was +135,000 ± 509,000 tons per year. For vegetable and melon crops, the best estimate slope between 2000-2006 was +125,000 ± 366,000 tons per year; between 2007-2009 the slope was -834,000 ± 59,000 tons per year.



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Total	69.43	63.08	71.96	66.97	70.06	68.57	67.55	71.54	73.10	66.10
Field and Seed Crops	28.55	25.87	29.11	28.41	29.17	28.22	28.30	29.96	31.23	25.92
Fruit and Nut Crops	15.44	13.84	14.30	14.10	13.21	14.97	13.71	13.92	14.93	14.19
Vegetable and Melon Crops	25.44	23.36	28.55	24.46	27.69	25.38	25.54	27.67	26.94	26.00

Figure 9: Yield of harvested crops in California, 2000-2009.
Source: USDA NASS California Agricultural Statistics, Crop Years 2000-2009. (USDA-NASS 2000-2009)

Note: Includes field and seed crop, fruit and nut crop, and vegetable and melon crop yields in million tons (excludes livestock, poultry, and aquaculture). Displayed black trend line is a linear trend of annual total yield.

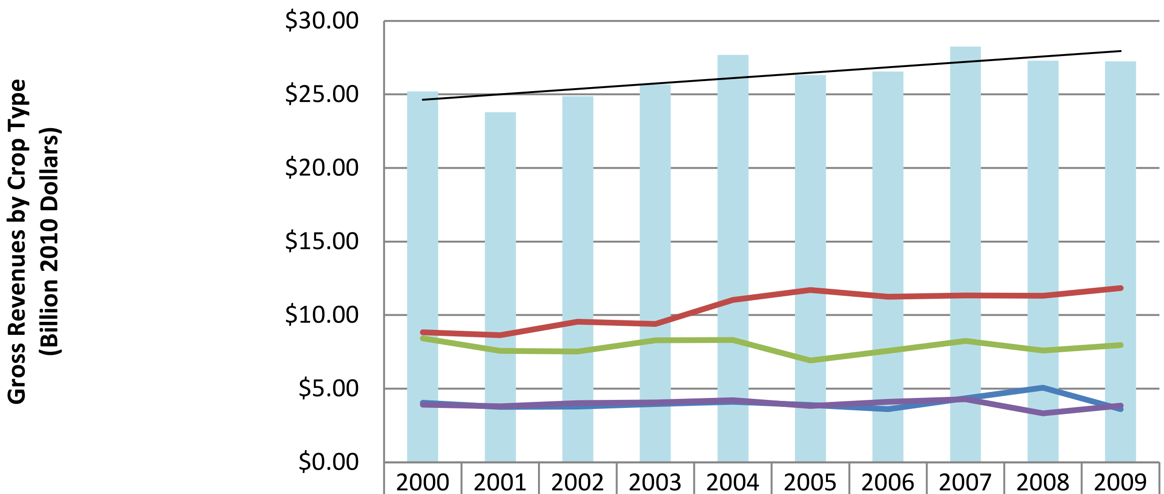
Revenue

Total gross revenues from irrigated crops have increased over the past decade, and total annual revenues for all principle crop types combined were higher in drought years than in all preceding years of the decade except 2004. Figure 10 demonstrates statistically significant long-term increase in gross revenue, particularly during the drought period.[11] Nevertheless, the drought period saw *annual* decreases in revenue for all crop types except fruit and nut crops. Field and seed crops experienced the greatest annual declines during the drought years, although drought

[11] The slope of gross revenue versus time between 2000-2009 (decade), 2000-2006 (pre-drought), and 2007-2009 (drought) was determined by ordinary least squares regression (95% confidence level), using annual harvested, irrigated crop production value data in 2010 dollars adjusted for inflation. The best-estimate slope for the 2000-2009 (decade) period is +$369,000,000 ± $98,000,000 per year (P-value = 0.005). The best-estimate slope for the 2000-2006 (pre-drought) period is +$427,000,000 ± $181,000,000 per year (P-value = 0.06). The best-estimate slope for the 2007-2009 (drought) period is -$499,000,000 ± $256,000,000 per year (P-value = 0.3).

year annual revenues for field and seed crops never dropped below the 2006 (wet year) revenues.[12]

Overall, the 37% (2 million acre) reduction in California's field and seed crop acres between 2000 and 2009 corresponds only to a $349 million (11% decrease) in gross revenue; while a 7% (162,600-acre) increase in fruit and nut crop acreage over the same period corresponds to a $3 billion (34% increase) in gross revenue. Thus, the small increase in valuable fruit and nut crops outweighed the economic loss of low-value field and seed crops, yielding a statewide increase in agricultural revenue of 8% or $2 billion between 2000 and 2009.[13] Revenue increases likely constituted a substantial redistribution of revenue from one group of farmers to another, highlighting the importance of regional and local drought impacts, discussed further below.



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Total	$25.20	$23.78	$24.88	$25.69	$27.69	$26.32	$26.56	$28.24	$27.29	$27.24
Field and Seed Crop	$4.05	$3.77	$3.79	$3.95	$4.11	$3.89	$3.61	$4.36	$5.07	$3.60
Fruit and Nut Crops	$8.84	$8.63	$9.56	$9.39	$11.04	$11.70	$11.25	$11.34	$11.32	$11.83
Vegetable and Melon Crops	$8.41	$7.58	$7.53	$8.28	$8.31	$6.91	$7.58	$8.25	$7.58	$7.97
Nursery and Floriculture	$3.91	$3.81	$4.01	$4.07	$4.22	$3.83	$4.11	$4.29	$3.32	$3.84

Figure 10: Gross revenues from harvested crops in California, 2000-2009.
Source: USDA NASS California Agricultural Statistics, Crop Years 2000-2009. (USDA-NASS 2000-2009)

[12] For each crop type, the slope of gross revenue versus time between 2000-2006 (pre-drought) and 2007-2009 (drought) was determined by ordinary least squares regression (95% confidence level), using annual crop production value data. For field and seed crops, the best estimate slope between 2000-2006 was -$26,000,000 ± $34,000,000 per year; between 2007-2009 the slope was -$376,000,000 ±$630,000,000 per year. For fruit and nut crops, the best estimate slope between 2000-2006 was +$531,000,000 ± $101,000,000 per year; between 2007-2009 the slope was +$242,000,000 ± 154,000,000 per year. For vegetable and melon crops, the best estimate slope between 2000-2006 was -$109,000,000 ± $103,000,000 per year; between 2007-2009 the slope was -$141,000,000 ± $304,000,000 per year. For nursery and floriculture crops, the best estimate slope between 2000-2006 was +$31,000,000 ± $29,000,000 per year; between 2007-2009 the slope was -$224,000,000 ± $428,000,000 per year.

[13] All values are reported in 2010 dollars.

Note: Includes field and seed crop, fruit and nut crop, vegetable and melon crop, and nursery and floriculture values (excludes livestock, poultry, and aquaculture values). Displayed black trend line is a linear trend of annual total gross revenue; values are in billion 2010 dollars adjusted for inflation.

The Role of Prices

From an economic perspective, it could be argued that declines in the production of some crops may have raised prices of those crops and produced higher total revenues at the expense of growers that fallowed land or shifted crops.[14] The redistribution of income from producers who reduced output to the remaining producers in the industry likely occurred in some regions. However, our analysis found that most decreases in output occurred in field and seed crops, of which California is not a major producer, and changes in revenue and yield were not always directly related to prices. Below, we present key observable relationships (or the lack thereof) between acreage, yield, revenue, and prices in the pre-drought and drought period to the degree that available data allows.

Almonds, processing tomatoes, and alfalfa hay are example of crops from each of the principal three crop type categories (fruit and nut, vegetable and melon, and field and seed) for which California is the leading national producer based on total annual state yield (USDA-NASS 2010). These crops are also top ranking crops for the state in terms of revenue (USDA-NASS 2010) and are primarily cultivated in the San Joaquin Valley region – an area greatly impacted by the drought. During the drought, California's almond and processing tomato acreage, yield, and revenue all increased compared to prior years. However, the price of almonds decreased slightly, while tomato prices increased – demonstrating that yield-price relationships can be complex, and different for every crop. Alternatively, the acreage and total yield of alfalfa hay decreased during the drought compared to prior years (although yield per acre increased slightly). Nevertheless, alfalfa hay price and total value increased during the drought.

In addition, declines in the production of some crops may be offset by increased production in other areas of the state, thereby having little effect on supply (and theoretically prices). For example, fallowing processing tomatoes in a water scarce region may not lead to scarcity-induced price increases if tomato production increases elsewhere. Michael et al. (2010) found that within Stanislaus County, fallowed acres in water-scarce areas (and therefore production decreases) paralleled planting of new acres in other areas with supplemental water supplies and groundwater access. Overall, tomato acreage increased in Stanislaus County a record 74%

[14] A key feature of many agricultural commodities is their relatively inelastic demand, meaning that demand for many California crops remains relatively steady regardless of changes in crop prices. Therefore, a decline in production of a crop (such as in response to water supply reductions) may cause prices to rise disproportionately more than the reduction in quantity supplied to the market. This leads to an increase in gross revenue for farmers and, unless their production costs also rise, an increase in net revenue. California produces a large enough share of certain crops (especially specialty fruits, nuts, and vegetables) that a reduction in California's production may trigger this type of increase in price and revenue (Ligon 2009).

between 2008 and 2009 (Stanislaus County 2009 Crop Report), while statewide acreage, yield and prices for tomatoes also rose. This is not the trend we would expect if supply was the only factor in driving price. Ultimately, gross revenues in Stanislaus County more than doubled from $61 million in 2007 to $125 million in 2009 (Stanislaus County 2009 Crop Report). Clearly, acreage, yield, and price relationships are not simple and there are a variety of confounding variables, including advances in the production of processing tomatoes through the widespread use of drip tape. The specific contribution of the drought in influencing or responding to crop prices could be part of a more in-depth economic analysis, but is beyond the scope of this report.

Table 4: Comparison of annual average pre-drought (2000-2006) and drought (2007-2009) changes in acreage, yield, and values for key California crops.

Measure	Almonds		Processing Tomatoes		Alfalfa Hay	
	2000-2006	2007-2009	2000-2006	2007-2009	2000-2006	2007-2009
Harvested Acres (1000 acres)	558	680	283	298	1,067	1,000
Yield per Acre (tons)	0.86	1.09	36.78	42.14	6.94	7.10
Total Production (1000 tons)	479	738	10,087	12,406	7,407	7,099
Price ($/ton)	$3,849	$3,324	$69.31	$80.35	$129.36	$163.64
Gross Revenue (million $)	$1.84	$2.41	$0.70	$1.00	$0.96	$1.17

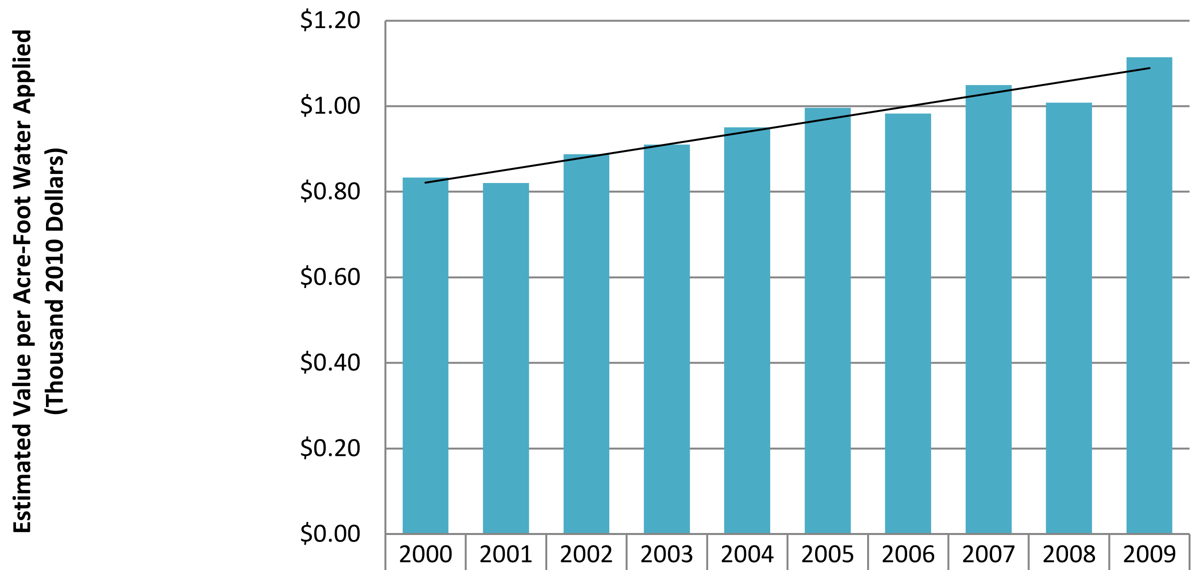
Source: USDA NASS California Agricultural Statistics, Crop Years 2000-2009. (USDA-NASS 2000-2009)

Note: Calculated amounts are averages over the two periods listed in the chart above. Values are in 2010 dollars adjusted for inflation.

Economic Productivity of Water

Naturally, water is valuable during a drought. Annual changes in the economic productivity of water, or output (the value of crops produced) per unit input (applied water), represents a measure of this value.[15] We found that the annual productivity of water in California increased during the drought compared to pre-drought years; the annual increase in the value per unit water during the drought period was larger than annual increases prior to the drought by roughly $2/AF per year (see Figure 11). Again, it is important to note that while we can identify the trend of increasing productivity, we cannot isolate the individual contributions of various causal factors.

[15] The slope of annual value per acre-foot of water versus time between 2000-2006 (pre-drought) and 2007-2009 (drought) was determined by ordinary least squares regression (95% confidence level), using USDA NASS Historical Data, 2010, and 1998-2008 USDA Census of Agriculture, Farm and Ranch Irrigation Survey (FRIS) data. The best estimate slope of the annual value/AF between 2000-2006 was +$30.76 ± $3.94 per year; between 2007-2009 the slope was +$32.57 ± $42.44 per year. Values are in 2010 dollars adjusted for inflation.



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Estimated Value (Thousand 2010 Dollars)	$0.83	$0.82	$0.89	$0.91	$0.95	$1.00	$0.98	$1.05	$1.01	$1.11

Figure 11: Estimated Production Value per Acre-Foot Water Applied in California, 2000-2009
Source: USDA NASS California Agricultural Statistics, Crop Years 2000-2009 and 1998-2008 USDA Census of Agriculture, Farm and Ranch Irrigation Survey.[16] (USDA-NASS 2000-2009, USDA-NASS 1998-2008)

Note: Estimates of value are calculated from water applied to relevant crops (fruit and nut, field and seed, vegetable and melon; excluding nursery and floriculture), and annual acreage and values for field and seed crops, fruit and nut crops, and vegetable and melon crops (excludes nursery and floriculture, and acres devoted to livestock, poultry, and aquaculture). Values are in 2010 dollars adjusted for inflation.

Individual County and Water District Reports

Statewide averages are useful to assess the impact of the drought on the state agricultural sector as a whole, but these averages can hide important local effects. Examining individual county crop reports over the drought period prepared by county agricultural commissioners, along with individual water district reports, provides finer-scale information about the relationship between water use and agricultural production in particular areas. Here, we highlight several individual county and water district reports that best reflect the varied impacts. First, we examine Fresno County located in the heart of the San Joaquin Valley, where the agricultural sector remained high-grossing throughout the drought. We then compare the trends in Fresno County with those in nearby Kern, Kings, and Tulare Counties, and examine data from the Westlands Water District, which straddles Fresno and Kings Counties. These comparisons shed light on the extremely localized nature of impacts and responses. It must be noted, however, that the crop

[16] FRIS data from Table 23/28: Estimated Quantity of Water Applied and Method of Distribution by Selected Crops Harvested, report years 1998 – 2008.

reports do not describe smaller micro-impacts within the county, such as crop revenue losses to individual communities and farms and are not a full accounting of all agricultural production in a county.

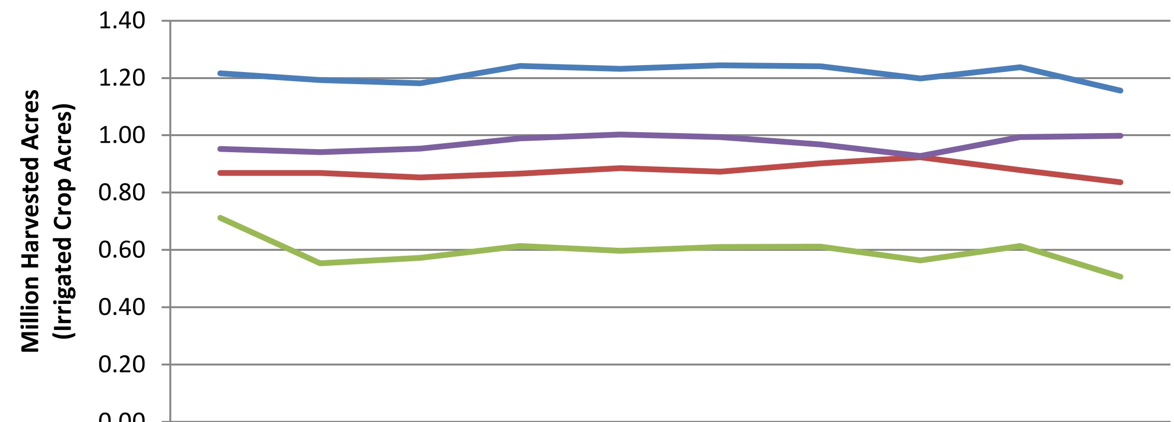
Taking Fresno, Kern, Kings, and Tulare Counties to be examples of particularly drought-affected San Joaquin Valley agricultural regions, drought-period impacts are most apparent in acreage, but also to some degree in yield and production values.

Acreage: Acreage changes differed across the counties, but Fresno, Kern, and Kings Counties saw decade lows in total crop acreage in 2009, while Tulare saw a decade high in crop acreage. Overall, declines in field and seed crop acreage, yield, and gross revenue in these counties were greater during the drought than they had been in prior years (see Figure 12).

Yield: Yield of the highest value crops during the drought varied between counties: there was gradual increase in the yield of high value crops in Fresno, while in the other three counties, 2008 peak yields of high values crops were followed by declines in 2009 (see Figure 13). There were decreases in the yield of specific crops, chiefly field and seed crops, such as cotton in Kings County. On average, yields of the majority of top-ranking (highest-grossing) crops were still higher during drought years than they were in 2006 (a wet year) in all four counties. Individually, Kern was the only county that saw a major decrease in a top crop commodity – citrus – in 2009.

Gross Revenue: Gross revenues over the drought years were more varied, but the average total gross revenue in all counties was between 13% and 29% higher during the drought (2007-2009) than during the years prior to the drought (2000-2006) (see Figure 14). Kern saw a steady decrease in gross revenue over the course of the drought, while Kings County saw decade high values in 2007 and 2008; revenues for both counties were less in 2009 than in both 2008 and 2006 (wet year). Fresno and Tulare gross revenues peaked in 2008, then dropped in 2009. This was similar to the decline in revenue experienced by Kern and Kings, nevertheless, there were higher gross revenues each year of the drought in these two counties than in 2006 (wet year). Overall, gross revenue diminished (by varying amounts) in all four of these San Joaquin Valley counties during the last year of the drought (2009 compared to 2008).

Summary: Observing changes in acreage, production, and values in San Joaquin Valley counties over the entire drought period, and in comparison to normal and wet years (2000 and 2006), supports the conclusion that Valley agriculture suffered short-term losses (moderated in part by crop shifting), yet managed to keep acreage, yield, and gross revenues relatively steady overall. The analysis of San Joaquin Valley counties that stood to be most affected by drought-induced water supply reductions shows that the Valley agricultural sector experienced declines in terms of acreage, gross revenue, and some crop yields between 2007 and 2009. Acreage declines were most dramatic in 2009, yet yields of top crop commodities and total production values remained steady or increased during the drought in Valley counties. Overall, gross revenues for all four counties were higher between 2007 and 2009 than between 2000-2006. Even in 2009, Kern and Kings counties' gross revenues were only 2% less than values in the most recent wet water year of 2006; Fresno and Tulare's were both 4% higher in 2009 than 2006. These trends are discussed in more detail below.

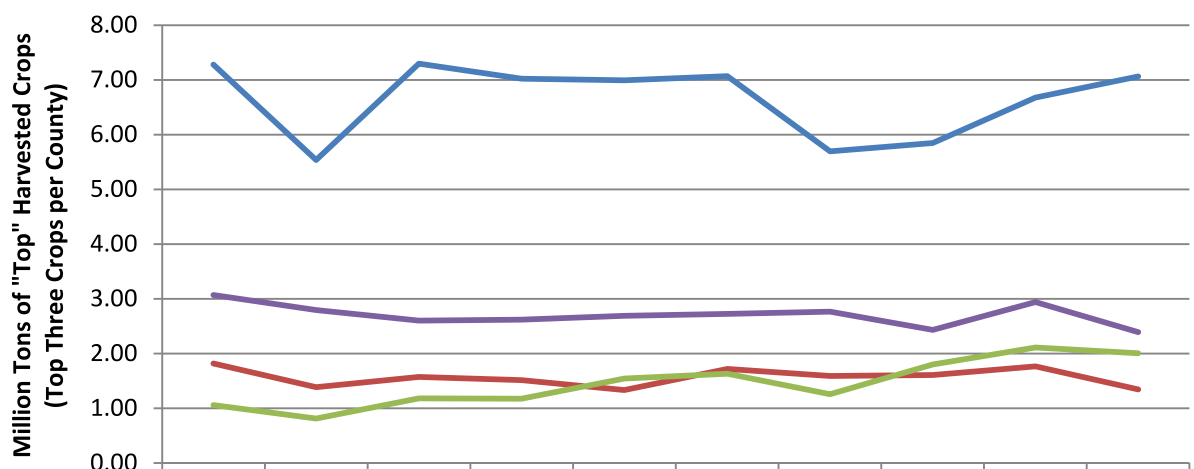


	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Fresno	1.22	1.19	1.18	1.24	1.23	1.24	1.24	1.20	1.24	1.16
Kern	0.87	0.87	0.85	0.87	0.89	0.87	0.90	0.92	0.88	0.84
Kings	0.71	0.55	0.57	0.61	0.60	0.61	0.61	0.56	0.61	0.51
Tulare	0.95	0.94	0.95	0.99	1.00	0.99	0.97	0.93	0.99	1.00

Figure 12. Comparison of total harvested, irrigated crop acreage in Fresno, Kern, Kings, and Tulare Counties, 2000-2009
Source: Fresno, Kern, Kings, and Tulare County Annual Crop Reports, years 2000-2009, County Agricultural Commissioners' Offices for Fresno, Kern, Kings, and Tulare Counties. (Fresno County 2000-2009, Kern County 2000-2009, Kings County 2000-2009, Tulare County 2000-2009)

Note: This chart compares different annual acreage amounts during the past decade in Fresno, Kern, Kings, and Tulare Counties. For Fresno and Kern counties, acres are from field and seed (excluding rangeland acreage), fruit and nut, vegetable and melon, and nursery and floriculture crops. For Kings and Tulare Counties, nursery and floriculture acreage is not reported, and is therefore excluded.[17]

[17] For all counties, nursery and floriculture acreage is a small percentage of total acreage, and therefore exclusions do not change the trends displayed here. Nursery acreage is available from the California Department of Food and Agriculture's Nursery, Seed and Cotton Program (CDFA 2011), and is reported separately from data reported to the county agricultural commissioners' offices and the USDA.

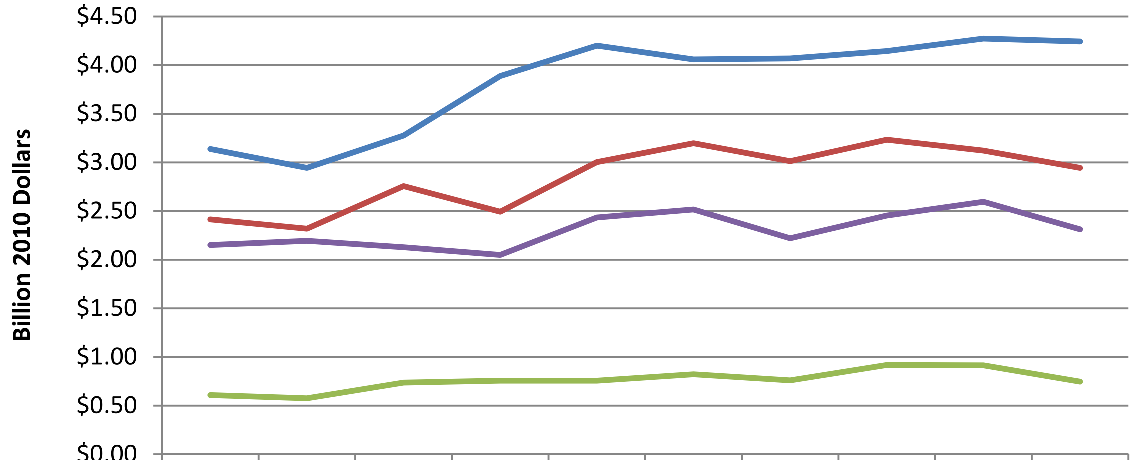


	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Fresno	7.28	5.53	7.29	7.02	6.99	7.07	5.69	5.84	6.68	7.06
Kern	1.82	1.38	1.57	1.51	1.33	1.72	1.59	1.61	1.76	1.34
Kings	1.06	0.81	1.18	1.17	1.54	1.63	1.26	1.80	2.11	2.01
Tulare	3.07	2.79	2.60	2.62	2.69	2.72	2.76	2.43	2.94	2.39

Figure 13. Comparison of yield (production in million tons) of the top three harvested, irrigated crops in Fresno, Kern, Kings, and Tulare Counties, 2000-2009.

Source: Fresno, Kern, Kings, and Tulare County Annual Crop Reports, years 2000, 2007-2009, County Agricultural Commissioner's Office for Fresno, Kern, Kings, and Tulare Counties. (Fresno County 2000-2009, Kern County 2000-2009, Kings County 2000-2009, Tulare County 2000-2009)

Note: Top crop commodities are the highest ranking crops in terms of gross revenue for the county over the past decade. This chart compares annual production in tons of the top three non-dairy/poultry crop commodities combined in Fresno, Kern, Kings, and Tulare Counties. Fresno County's top crops include: grapes (raisin, table, and wine); almonds (shelled); and tomatoes (fresh and processing). Kern County's top crops include: grapes (raisin, table, and wine); and citrus (grapefruit, lemons, oranges, tangerines, and processing citrus); and almonds (shelled). Kings County's top crops include: cotton (lint and seed); alfalfa hay; and tomatoes (processing). Tulare County's top crops include: grapes (raisin, table, and wine); oranges (Navels and Valencia); and alfalfa hay.



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Fresno	$3.14	$2.94	$3.27	$3.89	$4.20	$4.06	$4.07	$4.14	$4.27	$4.24
Kern	$2.41	$2.32	$2.76	$2.49	$3.00	$3.20	$3.01	$3.23	$3.12	$2.94
Kings	$0.61	$0.57	$0.74	$0.76	$0.76	$0.82	$0.76	$0.92	$0.91	$0.74
Tulare	$2.15	$2.19	$2.13	$2.05	$2.43	$2.52	$2.22	$2.45	$2.59	$2.31

Figure 14. Comparison of total gross revenue for harvested, irrigated crops in Fresno, Kern, Kings, and Tulare Counties, 2000-2009

Source: Fresno, Kern, Kings, and Tulare County Annual Crop Reports, years 2000, 2007-2009, County Agricultural Commissioner's Office for Fresno, Kern, Kings, and Tulare Counties. (Fresno County 2000-2009, Kern County 2000-2009, Kings County 2000-2009, Tulare County 2000-2009)

Note: This chart compares annual gross revenue during the past decade in Fresno, Kern, Kings, and Tulare Counties. For all counties, values are from field and seed (excluding rangeland values); fruit and nut; vegetable and melon; and nursery and floriculture crops (except for Kings County, where nursery and floriculture values are not reported and therefore excluded). Values are in 2010 dollars adjusted for inflation.

Fresno County

Fresno County is the top-earning agricultural county in California, and is consistently the highest dollar-earning agricultural county in the nation (USDA-NASS 2000-2009). Its highest value crops (excluding dairy and poultry), in order of production value, are fruits and nuts, vegetables and melons, field and seed crops, and nursery and floriculture crops. Fresno County covers parts of both the east and west sides of the San Joaquin Valley. The entire valley receives water deliveries from the Delta, however the west side of the San Joaquin Valley relies on SWP and CVP deliveries for over 80% of water in an average water year compare to only 14% for east side regions (Michael et al. 2010). The east side is far more water-secure with additional rights to local surface water supplies and access to groundwater.

Agricultural production data is aggregated across entire counties in county crop reports. Therefore, it is difficult to isolate the losses suffered on the west side of Fresno County. Overall, Fresno County's crop report figures demonstrate a surprising successful response to water supply reductions. (Later, we will examine employment data that allows us to disaggregate the county's west and east side employment trends.) In Fresno County, there were significant annual declines in harvested acreage, but simultaneous significant annual increases in gross revenue, during the drought (see Table 5).[18]

Table 5. Comparison of percentage change in total crop acreage and gross revenue in Fresno County, 2000-2009

Years	Percentage Change	
	Harvested Acres	Gross Revenue
2000-2001	-1.88%	-6.10%
2001-2002	-0.96%	11.23%
2002-2003	5.08%	18.73%
2003-2004	-0.80%	8.00%
2004-2005	1.02%	-3.39%
2005-2006	-0.30%	0.22%
2006-2007	-3.38%	1.93%
2007-2008	3.26%	3.06%
2008-2009	-6.60%	-0.72%

Source: Acreage and value data from Fresno County Annual Crop Reports, 2000-2009, Fresno County Agricultural Commissioner's Office. (Fresno County 2000-2009)

Note: This table compares annual percentage changes in acreage and gross revenue during the past decade. Acreage and values are for field and seed (excluding rangeland acreage and values); fruit and nut; vegetable and melon; and nursery and floriculture crops. Values are in 2010 dollars adjusted for inflation.

Trends in Fresno County during the drought years matched statewide trends over the last two decades, reflecting reduced agricultural acreage and shifts towards higher-value, permanent crops. Between the drought years of 2007 and 2009, Fresno County's total harvested acreage declined by 4%, and has declined by a total of 5% since 2000. Field and seed crop acreage in Fresno declined by 5% during the drought, and by a total of 25% since 2000. Meanwhile, fruit and nut crop acreage increased by 1% during the drought, and has increased by 24% since 2000 (coinciding with a 25% decrease in the field and seed crop acreage).

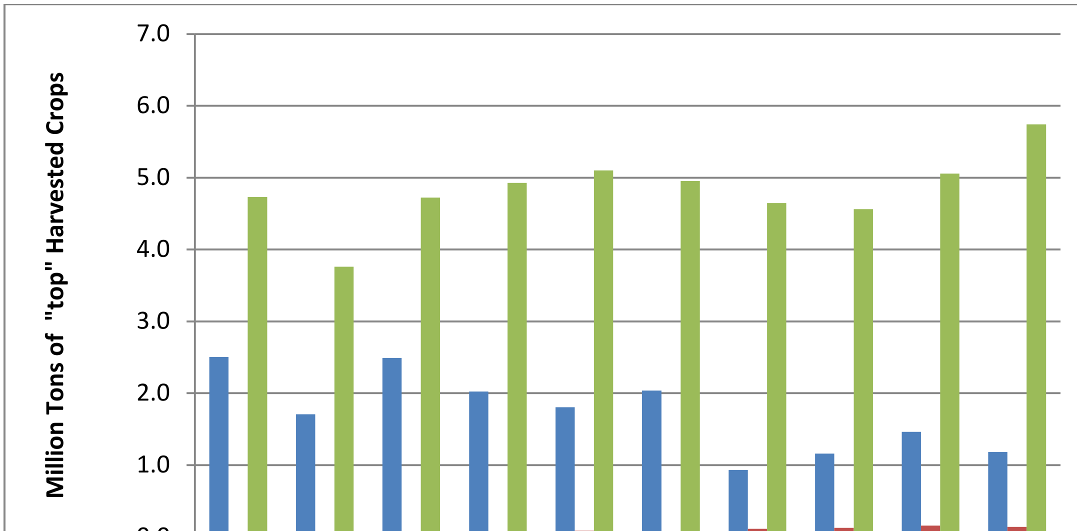
The total gross revenue of Fresno County agriculture increased by 2% during the drought years, and has increased by 35% since 2000. The only significant revenue decline in Fresno County, both during the drought and since 2000 has been in field and seed crop revenues, where gross revenues decreased by 27% during drought years, and were down 47% from 2000 levels.[19] Other crop categories saw increases in gross revenue, both during the drought and over the decade. Fruit and nut crop revenues increased by 5% during the drought, and total fruit and nut crop revenues in 2009 were 69% greater than they were in 2000. Vegetable and melon crops also saw substantial gains: 9% increase in revenue during the drought years and a 49% increase from 2000. We are unable to determine which Fresno County

[18] The slopes of acreage versus time and gross revenue versus time, from 2000-2006 (pre-drought) and 2007-2009 (drought), were determined by ordinary least squares regression (95% confidence level), using annual acreage data and crop production value data (values are 2010 dollars adjusted for inflation). For acreage, the best estimate slope from 2000-2006 was +8,000 ±4,000 acres per year; between 2007-2009 the slope was -21,000 ± 35,000 acres per year. Alternately, for gross revenue, the best estimate slope from 2000-2006 was +$212,000,000 ± $49,000,000 per year; from 2007-2009 the slope was +$48,000,000 ± $46,000,000 per year.

[19] Nursery and floriculture also declined in value, but these crops comprise on average only a small percentage of total county crop value.

producers these crop shifts either harmed or benefited, as data at the individual producer level is not available.

The production of the highest ranking irrigated crops[20] – those that generate the most revenue for Fresno County in recent years – showed mixed trends in yield over the drought years compared to prior years. In Fresno County, yields of grapes, almonds, and tomatoes were all higher in 2009 than in 2006 and 2007, even though there were annual declines in yield for grapes and almonds between 2008 and 2009 (see Figure 15). There were no dramatic declines in the yield of these three highest value crop commodities; yield of each was higher every year of the drought than in 2006 (wet water year) and lowest drought-period yields occurred in either 2007 or 2008, not 2009. Overall, there were steady increases each year of the drought in the combined total yield of Fresno's top-three ranking crops; combined production (yield in tons) of Fresno's top crop commodities increased significantly over the course of the drought (see Table 6).[21]



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Grapes	2.50	1.71	2.49	2.02	1.80	2.04	0.93	1.16	1.46	1.18
Almonds	0.05	0.07	0.08	0.07	0.09	0.08	0.12	0.13	0.16	0.14
Tomatoes	4.73	3.76	4.72	4.93	5.10	4.95	4.65	4.56	5.06	5.74

Figure 15: Annual yield of top crop commodities in Fresno County, 2000-2009
Source: Yield data from Fresno County Annual Crop Reports, years 2000-2009, Fresno County Agricultural Commissioner's Office. (Fresno County 2000-2009)

[20] Top ranking crops for counties can vary from year to year. The top three ranking crops identified in this report, for all counties, are those among the top three revenue-generating non-dairy/poultry, irrigated crop commodities produced in the county between 2007 and 2009 according to USDA Agricultural Statistics (USDA-NASS 2010).
[21] The slope of annual yield of the county's top three crop commodities versus time between 2000-2006 (pre-drought) and 2007-2009 (drought) was determined by ordinary least squares regression (95% confidence level), using annual yield data (tons). The best estimate slope from 2000-2006 was -71,000 ± 152,000 tons per year; from 2007-2009 the slope was +610,000 ± 129,000 tons per year.

Note: Top crop commodities are the highest ranking crops in terms of gross revenue for the county over the past decade. This chart compares tons produced annually of the top three non-dairy/poultry crop commodities in Fresno County. Grapes include all grapes (raisin, table, and wine); almonds are shelled almonds; tomatoes include fresh and processing tomatoes.

Table 6. Comparison of annual yield and value relationships over the drought period for top Fresno crop commodities

Year	Grapes			Almonds			Tomatoes		
	Tons Produced	Value per Ton	Total Value	Tons Produced	Value per Ton	Total Value	Tons Produced	Value per Ton	Total Value
2006	930,900	$654	$608,690,329	115,000	$4,651	$534,867,762	4,645,000	$94	$434,969,174
2007	1,158,900	$557	$645,419,961	126,000	$3,986	$502,214,154	4,560,000	$110	$499,602,859
2008	1,460,400	$502	$732,457,964	159,000	$3,504	$557,174,081	5,058,000	$90	$457,285,025
2009	1,180,560	$575	$678,587,037	140,000	$3,431	$480,391,136	5,744,000	$109	$624,817,462

Source: Fresno County Annual Crop Reports, years 2006-2009, Fresno County Agricultural Commissioner's Office. (Fresno County 2000-2009)

Note: Red squares indicate an annual decrease in either yield or value from the previous year; green squares indicate an annual increase. Values are in 2010 dollars adjusted for inflation. This table allows comparison of yield and value data for key Fresno crops during the drought years, in order to show price changes during drought years that may respond to changes in output (yield). Top crop commodities are the highest ranking crops in terms of crop production value for the county over the past decade. Grapes include all grapes (raisin, table, and wine); almonds are shelled almonds; tomatoes include fresh and processing tomatoes.

When comparing annual changes, the relationships between yield, prices, and gross revenue are varied. For example, in 2009, Fresno County produced more than 40% of the state's processing tomatoes, and in that year, revenue rose with production and prices. Comparing 2006 (wet year) to 2009 (last year of the drought), instead of comparing subsequent years, we see different relationships, such as grape and almond yields increasing despite overall price decreases between 2006 and 2009. Using either method of comparison, we find no evidence of severe economic impacts to the county's highest grossing crops during the drought period.

Kern and Kings Counties

Kern and Kings Counties are two neighboring Central Valley counties with productive, valuable farmland. Both were directly affected by water-supply reductions during the drought. Kern and Kings Counties are south of Fresno, and are dependent on the SWP. In Kern County, harvested acreage declined by 9% between 2007 and 2009 – 5% greater than the decline in Fresno County (see Table 7). Unlike in Fresno, where gross revenue increased both during the drought and over the past decade, Kern's gross revenue was also down 9% between 2007 and 2009. However, in the long-term, Kern's gross revenue trends are similar to those of Fresno: drought period (2007-2009) average gross revenue was 28% higher than in 2000 (2009 alone was 22% higher than 2000). Kern was the only county out of the four we discuss here to experience a significant decline in a top-ranking crop during the drought: citrus. During the last year of the drought, citrus yield was 37% less than in 2006. Kern County maintained or increased yields in other top-ranking crop commodities compared to 2006, and produced relatively steady yields in those crops compared to past decade averages.

In Kern County, there was a significant decline in annual harvested acres and production values over the drought period.[22] Nevertheless, Kern's drought period (2007-2009) total value and acreage averages are higher than averages in pre-drought years (2000-2006).

Table 7. Comparison of annual percentage change in total harvested, irrigated crop acreage and gross revenue in Kern County 2000-2009

Years	Annual Percentage Change	
	Harvested Acres	Gross Revenue
2000-2001	0.00%	-3.92%
2001-2002	-1.80%	18.89%
2002-2003	1.55%	-9.53%
2003-2004	2.27%	20.35%
2004-2005	-1.45%	6.52%
2005-2006	3.34%	-5.81%
2006-2007	2.31%	7.33%
2007-2008	-4.82%	-3.44%
2008-2009	-4.82%	-5.72%

Source: Acreage and value data from Kern County Annual Crop Reports, 2000-2009, Kern County Agricultural Commissioner's Office. (Kern County 2000-2009)

Note: This table compares annual percentage changes in acreage and gross revenue during the past decade. Acreage and values are for field and seed (excluding rangeland acreage and values); fruit and nut; vegetable and melon; and nursery and floriculture crops. Values are in 2010 dollars adjusted for inflation.

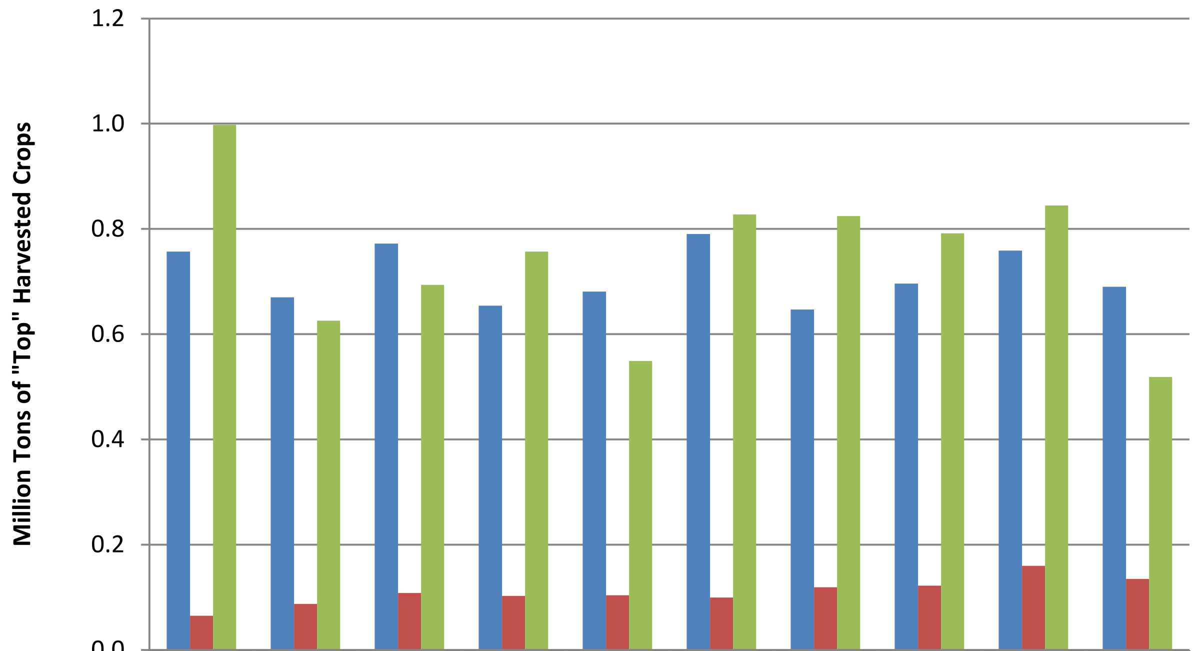
Similar to Fresno, the relationships between yield, prices, and gross revenue are different for different crops, and for different yearly comparisons, such as between consecutive years and between 2006 and 2009 (see Figure 16). The total yield of Kern County's top crop commodities decreased more significantly over the course of the drought (2007-2009) than prior to the drought (2000-2006) (see Table 8).[23] Citrus is one of the top three major revenue-generating crops for Kern County. There was a notable reduction in citrus production in 2009 by 40%, and a corresponding 12% increase in price. Nevertheless, the price increase was not so dramatic that Kern County did not suffer reduced total gross revenue. In 2008, Kern County's citrus yield generated approximately 39% of the state's total gross revenue for citrus, [24] which dropped to 27% in 2009. The loss

[22] The slopes of acreage versus time and gross revenue versus time, from 2000-2006 (pre-drought) and 2007-2009 (drought), were determined by ordinary least squares regression (95% confidence level), using annual acreage data and crop production value data (values are 2010 dollars adjusted for inflation). For acreage, the best estimate slope from 2000-2006 was +5,000 ±2,000 acres per year; from 2007-2009 the slope was -43,000 ± 620 acres per year. For gross revenue, the best estimate slope from 2000-2006 was +$136,000,000 million per year ± $36,000,000 million; from 2007-2009 the slope was -$145,000,000 ± $19,000,000 per year.

[23] The slope of annual yield of the county's top three crop commodities versus time between 2000-2006 (pre-drought) and 2007-2009 (drought) was determined by ordinary least squares regression (95% confidence level), using annual yield data (tons). The best estimate slope between 2000-2006 was -9,000 ± 35,000 tons per year; between 2007-2009 the slope was -133,000 ± 165,000 tons per year.

[24] Citurs includes lemons, grapefruit, Navel and Valencia oranges, and tangerines. Data from Kern County 2009 and USDA-NASS 2010.

to Kern County farmers of over $150 million (compared to 2008) from citrus is equivalent to 5% of the county's 2009 total gross irrigated crop revenue of $2.9 billion. Yield decreased less significantly for grapes (10%) and almonds (16%) between 2008 and 2009. Yet, yield for both grapes and almonds were higher in 2009 than in 2006, although grapes experienced a price increase, while almonds experienced a price decrease between the two years.



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Grapes	0.76	0.67	0.77	0.65	0.68	0.79	0.65	0.70	0.76	0.69
Almonds	0.06	0.09	0.11	0.10	0.10	0.10	0.12	0.12	0.16	0.14
Citrus	1.00	0.63	0.69	0.76	0.55	0.83	0.82	0.79	0.84	0.52

Figure 16. Annual yield of top harvested, irrigated crop commodities in Kern County, 2000-2009
Source: Crop production data from Kern County Annual Crop Reports, years 2000, 2007-2009, Kern County Agricultural Commissioner's Office (Kern County 2000-2009)

Note: Top crop commodities are the highest ranking crops in terms of crop production value for the county over the past decade. This chart compares the tons produced annually of the top three non-dairy/poultry crop commodities in Kern County. Grapes include all grapes (raisin, table, and wine); almonds include shelled almonds; citrus includes grapefruit, lemons, oranges, tangerines, and processing citrus.

Table 8: Comparison of annual yield and value relationships over the drought period for top Kern crop commodities.

Year	Grapes			Almonds			Citrus		
	Tons Produced	Value per Ton	Total Value	Tons Produced	Value per Ton	Total Value	Tons Produced	Value per Ton	Total Value
2006	646,760	$823	$532,283,740	119,000	$4,323	$514,381,624	824,700	$509	$419,677,040
2007	696,000	$875	$609,314,051	122,000	$3,592	$438,166,442	791,370	$598	$473,211,218
2008	758,600	$750	$568,659,074	160,000	$2,232	$357,080,993	844,250	$584	$493,267,285
2009	690,200	$979	$675,396,559	135,000	$3,050	$411,692,683	518,700	$652	$338,385,874

Source: Kern County Annual Crop Reports, years 2006-2009, Fresno County Agricultural Commissioner's Office.

Note: Red squares indicate an annual decrease in either yield or value from the previous year; green squares indicate an annual increase. Values are in 2010 dollars adjusted for inflation. This table allows comparison of yield and value data for key Kern crops during the drought years, in order to show price changes during drought years that may respond to changes in output (yield). Top crop commodities are the highest ranking crops in terms of crop production value for the county over the past decade. Grapes include all grapes (raisin, table, and wine); almonds include shelled almonds; citrus includes grapefruit, lemons, oranges, tangerines, and processing citrus.

Similar to Fresno County, total acreage in Kings County reached a decade low in 2009, and average total acreage was lower during the drought than prior. In Kings County, there was a significant decrease in annual harvested acres over the drought period compared to the pre-drought period (See Table 9).[25] Gross revenue decreased by 19% over the drought years, as compared to 2006. Nevertheless, the county's average gross revenue was higher during the drought (2007-2009) than pre-drought (2000-2006).

Table 9. Comparison of percentage change in total harvested, irrigated, acreage and gross revenue in Kings County, 2000-2009

Years	Percentage Change	
	Harvested Acres	Gross Revenue
2000-2001	-22.28%	-5.27%
2001-2002	3.51%	28.02%
2002-2003	7.25%	2.75%
2003-2004	-2.71%	0.00%
2004-2005	2.29%	8.87%
2005-2006	0.04%	-7.67%
2006-2007	-7.71%	20.79%
2007-2008	8.89%	-0.33%
2008-2009	-17.51%	-18.59%

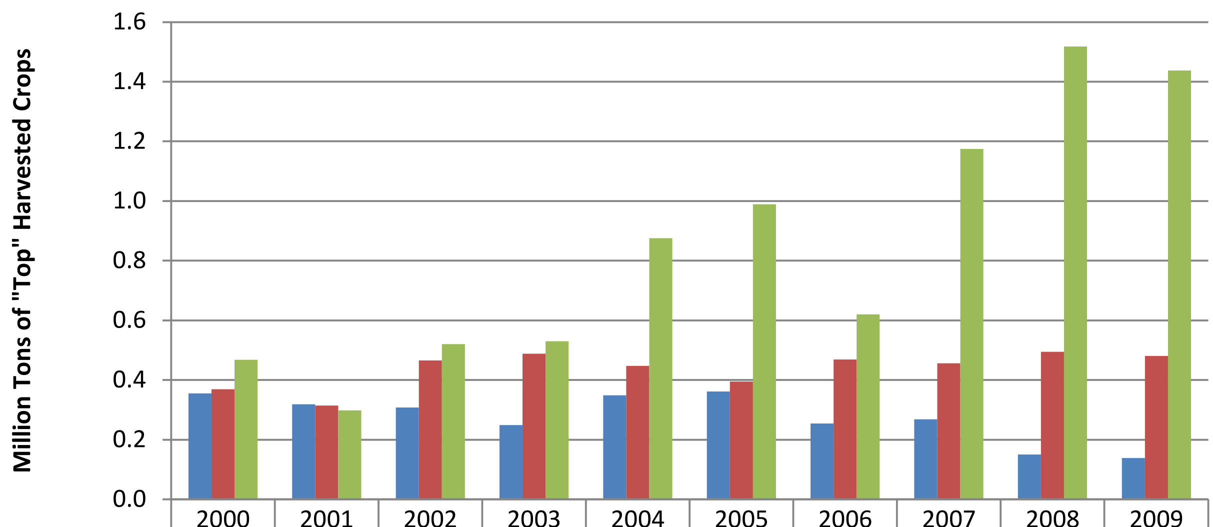
Source: Acreage and value data from Kings County Annual Crop Reports, 2000-2009, Kings County Agricultural Commissioner's Office. (Kings County 2000-2009)

Kings County experienced decreases in field and seed crop acreage during

[25] The slopes of acreage versus time and gross revenue versus time, from 2000-2006 (pre-drought) and 2007-2009 (drought), were determined by ordinary least squares regression (95% confidence level), using annual acreage data and crop production value data (values are 2010 dollars adjusted for inflation). For acreage, the best estimate slope from 2000-2006 was -6,000 ± 10,000 acres per year; from 2007-2009 the slope was -29,000 ± 46,000 acres per year. For gross revenue, the best estimate slope from 2000-2006 was +$35,000,000 ± $10,000,000 per year; from 2007-2009 the slope was -$87,000,000 ± $48,000,000 per year.

the drought and in the long-term, and decreases in field and seed crop revenues during the drought, where revenues had been relatively steady prior. While there is a longer-term overall increase in fruit and nut crop acreage and gross revenues in Kings County, there were declines in both fruit and nut acreage and revenues during the drought. Vegetable and melon crops demonstrated drought-period acreage and gross revenue trends similar to Fresno and Kern Counties: vegetable and melon crop acreage was steady-to-increasing prior to the drought, but dropped during the drought, and vegetable and melon crop values rose both before and during the drought.

Kings County demonstrates more significant drought period declines in both acreage and revenue across all crop types. Where Fresno and Kern counties experienced minor (between 1% and 8%) increases in both fruit and nut crop acreage and revenue during the drought years, Kings County experienced a 5% decrease in fruit and nut crop acreage during the drought, and a 22% decrease in fruit and nut crop revenue (see Figure 17). Annual decreases in the yield of Kings County's top crop commodities are evident before the drought, and annual decreases were only slightly greater during drought than they were in pre-drought years.[26]



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Cotton	0.36	0.32	0.31	0.25	0.35	0.36	0.25	0.27	0.15	0.14
Alfalfa Hay	0.37	0.31	0.47	0.49	0.45	0.40	0.47	0.46	0.49	0.48
Tomatoes	0.47	0.30	0.52	0.53	0.88	0.99	0.62	1.17	1.52	1.44

Figure 17: Annual yield of top irrigated crop commodities in Kings County, 2000-2009
Source: Crop production data from Kings County Annual Crop Reports, years 2000-2009, Kings County Agricultural Commissioner's Office. (Kings County 2000-2009)

[26] The slope of annual yield of the county's top three crop commodities versus time between from 2000-2006 (pre-drought) and 2007-2009 (drought) was determined by ordinary least squares regression (95% confidence level), using annual yield data (tons). The best estimate slope between from 2000-2006 was -92,000 ± 40,000 tons per year; between 2007-2009 the slope was -102,000 ± 118,000 tons per year.

Note: Top crop commodities are the highest ranking crops in terms of crop production value for the county over the past decade. This chart compares yield in tons produced annually of the top three non-dairy/poultry crop commodities in Kings County. Cotton includes lint and seed; tomatoes are processing tomatoes only. Significant annual decreases in the combined production (yield in tons) of these top crop commodities are evident before the drought, and were only slightly more significant over the course of the drought than they were in pre-drought years.

Table 10: Comparison of annual yield and value relationships over the drought period for top Kings County crop commodities.

Year	Cotton			Alfalfa Hay			Tomatoes		
	Tons Produced	Value per Ton	Total Value	Tons Produced	Value per Ton	Total Value	Tons Produced	Value per Ton	Total Value
2006	254,116	$925	$235,180,652	469,096	$138.45	$64,945,601	620,756	$61	$37,599,743
2007	268,244	$921	$246,969,810	456,350	$197.25	$90,015,530	1,174,970	$63	$74,140,582
2008	150,743	$945	$142,426,067	494,376	$214.88	$106,230,109	1,517,750	$67	$102,375,446
2009	138,330	$1,004	$138,861,538	481,281	$118.51	$57,036,283	1,437,133	$73	$104,878,216

Source: Kings County Annual Crop Reports, years 2006-2009, Fresno County Agricultural Commissioner's Office. (Kings County 2000-2009)

Note: Red squares indicate an annual decrease in either yield or value from the previous year; green squares indicate an annual increase. Values are in 2010 dollars adjusted for inflation. This table allows comparison of yield and value data for key Kings County crops during the drought years, in order to show price changes during drought years that may respond to changes in output (yield). Top crop commodities are the highest ranking crops in terms of crop production value for the county over the past decade. Cotton includes lint and seed; Tomatoes are processing tomatoes only.

Kings County is an example of a San Joaquin Valley County where field and seed crops are top ranking irrigated crop commodities. Kings is ranked first among California counties in the production of cotton lint and cottonseed (Kings County, 2009). The yield of cotton lint and seed in the drought years of 2008 and 2009 were less than 50% of the 2000-2006 average yield. Similar to the case of citrus in Fresno, cotton prices rose alongside the decreases in yield, however gross revenue declined overall (Table 10). Nevertheless, Kings County's 2009 cotton generated 45% of the state's 2009 cotton revenue, 10% more than in 2007 when the yield was nearly double that of 2009. For alfalfa, price fluctuations, not yield, appeared to mirror changes in gross revenue during the drought. Kings County substantially increased its production and revenue from processing tomatoes over the course of the drought.

Tulare County

Tulare County is an example of a San Joaquin Valley region that did not fallow significant land as a result of the drought. In Tulare, acreage increased between 2007 and 2009, from a low in 2007 of 930,000 acres to just under 1 million acres in 2009. Total harvested acreage in the first year of the drought was lower than in 2000 (a normal water year) and 2006 (a wet water year);

however, Tulare harvested more acres in 2008 and 2009 than it did in both 2000 and 2006. Tulare also had higher gross crop revenue in every year of the drought than it did in 2000 or 2006.

In Tulare County, there was a significant increase in crop acreage, but a significant decrease in annual gross revenue, over the entire drought period compared to the pre-drought period (see Table 11).[27] Nevertheless, the county's average total acreage and gross revenue were higher during the drought (2007-2009) than before (2000-2006).

Table 11. Comparison of percentage change in total acreage and gross revenue in Tulare County, 2000-2009

Years	Percentage Change	
	Harvested Acres	Gross Revenue
2000-2001	-1.24%	1.99%
2001-2002	1.36%	-3.06%
2002-2003	3.75%	-3.72%
2003-2004	1.35%	18.83%
2004-2005	-0.95%	3.39%
2005-2006	-2.58%	-11.73%
2006-2007	-4.08%	10.45%
2007-2008	7.00%	5.78%
2008-2009	0.45%	-10.97%

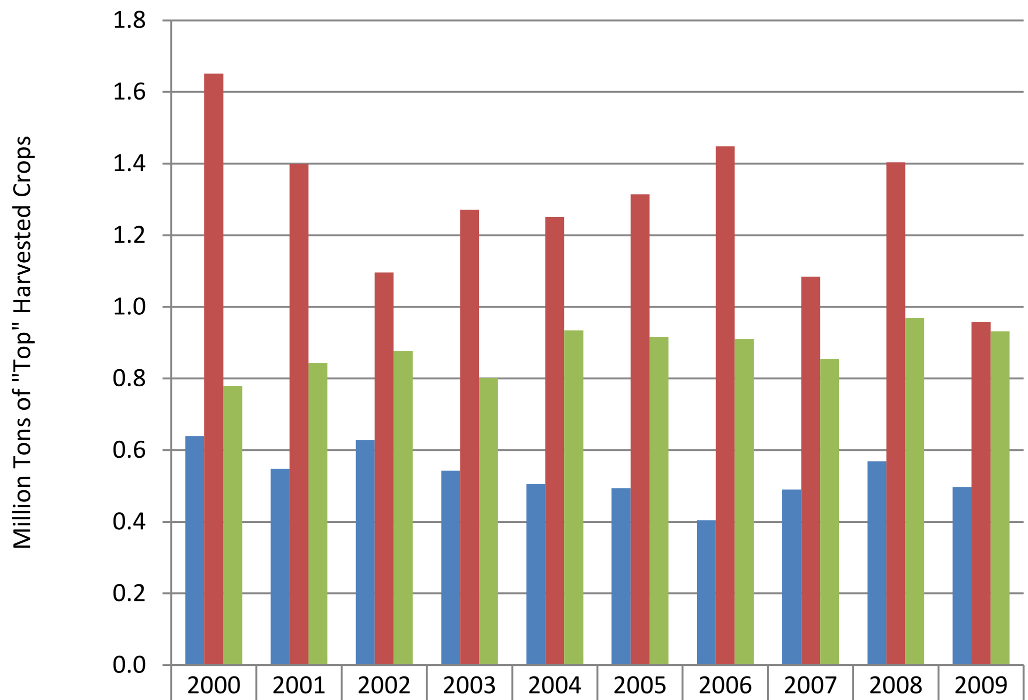
Source: Acreage and value data from Tulare County Annual Crop Reports, 2000-2009, Tulare County Agricultural Commissioner's Office. (Tulare County 2000-2009)

Note: This table compares annual percentage changes in acreage and gross revenue during the past decade (includes only non-dairy/poultry acreage and values; includes nursery and floriculture values, but excludes nursery and floriculture crop acreage, which Tulare County does not provide). Values are in 2010 dollars adjusted for inflation.

Yields of top-ranking crops in the county during the drought were mixed: yields of oranges declined between 2006 and 2009, but yields remained steady for both grapes and alfalfa (see Figure 18). Between 2008 and 2009, orange yields declined by 32% (this was down 34% from the 2006 yield). During this same period, there was a 16% price increase, but nevertheless a 21% decrease in total gross revenue. The trend was the opposite in 2007 and 2008, with increases in production, decreases in price, and increases in total revenue from this crop. Overall, the county produced fewer tons of top ranking crops in 2007 and 2009 than it did in both 2000 and 2006 (normal and wet water years), but yields in 2008 were higher than in 2006, and close to 2000 yields (see Table 12). This demonstrates that yields, as well as revenues, do not directly correspond to

[27] The slopes of acreage versus time and gross revenue versus time, from 2000-2006 (pre-drought) and 2007-2009 (drought), were determined by ordinary least squares regression (95% confidence level), using annual acreage data and crop production value data (values are 2010 dollars adjusted for inflation). For acreage, the best estimate slope from 2000-2006 was +7,000 ± 4,000 acres per year; from 2007-2009 the slope was +35,000 ± 18,000 acres per year. For gross revenue, the best estimate slope from 2000-2006 was +$41,000,000 ± $30,000,000 per year; from 2007-2009 the slope was -$72,000,000 ± $123,000,000 per year.

water supply or even acreage fluctuations. Yield was declining slightly before the drought, and continued to do so during the drought to no more a significant degree.[28]



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Grapes	0.64	0.55	0.63	0.54	0.51	0.49	0.40	0.49	0.57	0.50
Oranges	1.65	1.40	1.10	1.27	1.25	1.31	1.45	1.08	1.40	0.96
Alfalfa Hay	0.78	0.84	0.88	0.80	0.93	0.92	0.91	0.86	0.97	0.93

Figure 18. Annual yield of top irrigated crop commodities in Tulare County, 2000-2009
Source: Crop production data from Tulare County Annual Crop Reports, years 2000-2009, Tulare County Agricultural Commissioner's Office. (Tulare County 2000-2009)

Note: Top crop commodities are the highest ranking crops in terms of crop production value for the county over the past decade. This chart compares yield in tons produced annually of the top three non-dairy/poultry crop commodities in Tulare County. Grapes include raisin, table, and wine grapes; oranges include Navels and Valencia.

[28] The slope of annual yield of the county's top three crop commodities versus time from2000-2006 (pre-drought) and 2007-2009 (drought) was determined by ordinary least squares regression (95% confidence level), using annual yield data (tons). The best estimate slope from 2000-2006 was -35,000 ± 29,000 tons per year; from 2007-2009 the slope was -21,000 ± 308,000 tons per year.

Table 12: Comparison of annual yield and value relationships over the drought period for top Tulare County crop commodities.

	Oranges			Grapes			Alfalfa Hay		
Year	Tons Produced	Value per Ton	Total Value	Tons Produced	Value per Ton	Total Value	Tons Produced	Value per Ton	Total Value
2006	1,448,200	$423	$612,320,291	404,230	$937.26	$378,870,253	910,000	$146	$132,878,675
2007	1,084,000	$518	$561,174,941	489,830	$1,025.46	$502,301,442	855,000	$196	$167,246,968
2008	1,404,000	$428	$600,376,493	568,420	$869.56	$494,275,008	969,000	$216	$209,035,989
2009	958,000	$496	$475,109,924	497,460	$906.93	$451,159,482	932,000	$111	$103,254,009

Source: Tulare County Annual Crop Reports, years 2006-2009, Fresno County Agricultural Commissioner's Office. (Tulare County 2000-2009)

Note: Red squares indicate an annual decrease in either yield or value from the previous year; green squares indicate an annual increase. Values are in 2010 dollars adjusted for inflation. This table allows comparison of yield and value data for key Tulare County crops during the drought years, in order to show price changes during drought years that may respond to changes in output (yield). Top crop commodities are the highest ranking crops in terms of crop production value for the county over the past decade. Grapes include raisin, table, and wine grapes; oranges include Navels and Valencia.

Westlands Water District

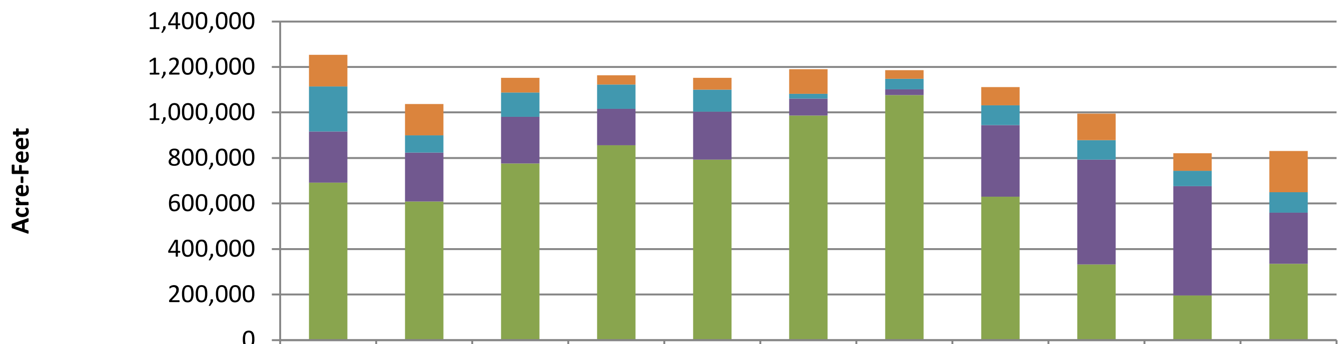
California water districts were created over the past century to manage agricultural water rights and contracts and to distribute water from state and federal water projects to individual farms. More than 500 water districts currently supply water for agricultural purposes in the state. Importantly, water district boundaries are different from county boundaries, watershed boundaries, or groundwater boundaries, and their record-keeping relates directly to water supply, making them particularly useful for understanding the specific relationship between water use and agricultural production.

Westlands Water District (Westlands) serves more than 600,000 acres of farmland on the west side of the San Joaquin Valley in Fresno and Kings Counties, providing water for approximately 600 farms averaging 900 acres in size (WWD 2011a). Water from outside the District is delivered to Westlands farmers from the CVP via the San Luis Canal (WWD 2011a). Westlands is the largest single user of water from the CVP, accounting for 30% of total water exported south of the Delta (Delta Vision Task Force and ENTRIX, Inc. 2008). The surface water supply is allocated to more than 535,000 acres eligible to receive CVP water; an additional 33,000 acres are ineligible to receive CVP water and rely solely on pumped groundwater (Westlands 2011a).

This section reviews Westlands Water District data on cropped acreage and estimates production values over the past several years, including during the drought. During the drought, representatives of Westlands regularly claimed severe damages were resulting from the drought, and from the impacts of environmental pumping restrictions in the Delta (see Employment and Poverty section for examples of press coverage). Westlands receives the majority of its water supply in many years from the CVP and supplements this with groundwater and minimal additional sources. However, Westlands has relatively insecure water contracts, compared to settlement and exchange contractors and is therefore often the first region to be affected by shortages in federal water project deliveries (see Impacts to Federal and State Water Project Deliveries section). Reductions in CVP water can occur for a variety of different reasons, including hydrologic conditions that limit the amount of freshwater flowing through the Delta system that supplies the CVP, or legal restrictions put in place to protect water quality for human and industrial uses as well as the environment. In 2010, Westlands requested a temporary restraining order against the Delta pumping restriction (see Sidebar 2), which was ultimately denied by Judge Wanger. Up-to-date data from the district now show relatively minor losses in estimated revenue (see Figure 21) because the district was able to identify and obtain supplemental water supplies (see Figure 19), including a large-scale shift to groundwater, and prioritize the irrigation of higher-value crops while fallowing lower-value, more water-intensive field and seed crop acres.

The district's primary annual contract entitlements from the CVP total 1.15 million acre-feet (Westlands 2011a). According to the district’s water supply data over the past 10 years, local and imported water supplies are supplemented by additional sources, such as groundwater and short-term water transfers (see Figure 19). The data indicate that during the 2007-2009 drought, as CVP allocations declined, intra-district transfers decreased slightly and groundwater use significantly increased. The district used 315,000 acre-feet groundwater in 2007 (a year during which the district received 50% of its CVP allocation) and 480,000 acre-feet in 2009 (a year with 10% CVP allocation). In 2009, Westlands’ groundwater use was more than double that of previous dry years (2000, 2001).[29] This is just under levels reached during the 1977 drought, when pumping also increased to nearly 500,000 acre-feet (Westlands 2011b). By utilizing alternate water supplies, particularly groundwater, Westlands’ total water supply was reduced by 3% in 2006; 13% in 2007; and 28% in 2009 (compared to the average water supply between 1993 and 2009), much less than what the district’s water supply would have been reduced had groundwater not been available for pumping.

[29] Westlands’s annual “safe yield” of the confined underground aquifer provides between 135,000 and 200,000 acre-feet of water per year. Safe yield is defined as “the maximum quantity of water that can be annually withdrawn from a groundwater basin over a long period of time during which water supply conditions approximate average conditions without developing an overdraft condition,” and varies annually (Westlands Water District Groundwater Management Plan, 1996. Available at: http://www.westlandswater.org). One-third of the total groundwater pumped within the district is from privately owned and operated wells, and the remaining comes from wells integrated into the district's water supply system. The district surveys groundwater levels in all wells, and the water quantity and quality of pumped groundwater, and publishes the results in the Deep Groundwater Conditions Report available at the District’s website: http://www.westlandswater.org. (See WWD 2011b.)



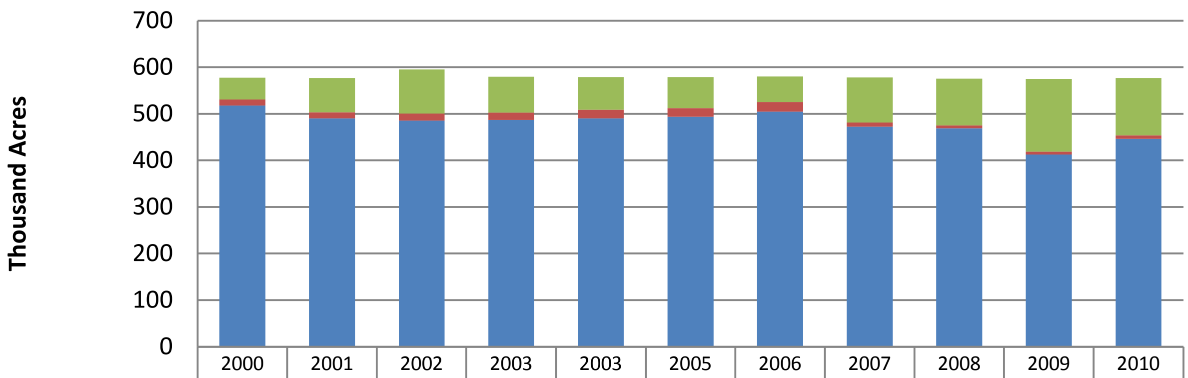
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Additional	137,802	138,106	64,040	40,362	51,728	108,335	38,079	79,810	117,537	77,424	180,000
Water User Acquired	198,294	75,592	106,043	107,958	96,872	20,776	45,936	87,554	85,421	68,070	90,000
Groundwater	225,000	215,000	205,000	160,000	210,000	75,000	25,000	315,000	460,000	480,000	225,000
Net CVP	691,624	608,200	776,526	855,306	793,383	986,159	1,076,4	629,520	332,547	195,716	335,212

Figure 19. Westlands Water District water supply sources, 2000-2009
Source: Westlands Water District 2011 (WWD 2011a)

Note: Water supply in acre-feet reported by the District. "Net CVP" is CVP allocation adjusted for carry-over and rescheduled losses; "Groundwater" is total groundwater pumped by the WWD; "Water User Acquired" includes intra-district transfers between private landowners; "Additional" includes surplus water, supplemental supplies, and other adjustments.

Irrigated crop reports from Westlands track cropping patterns within the district between 2000 and 2009 (Westlands 2011c). These reports show that fallowed acreage increased substantially during the drought in comparison to previous years (see Figure 20). In 2000 and 2006 (normal and wet water years, respectively), Westlands fallowed roughly 45,000 and 55,000 acres. During the 2007-2009 drought years, the district fallowed between 99,663 and 156,239 acres annually.[30]

[30] Westlands reports additional "non-harvested" acres separate from "fallowed" acres; average non-harvested acres between 2000 and 2006 were 1,375 acres. In 2009, Westlands reported an additional and unusually high 41,156 non-harvested acres. Addition of both fallowed and non-harvested acres in 2009 brings the total number of acres of cropland in Westlands above the normal annual total. We therefore assume that at least some portion of the additional non-harvested acres were included in the acres listed as "fallowed".



	2000	2001	2002	2003	2003	2005	2006	2007	2008	2009	2010
Fallowed	46.75	73.80	94.56	76.65	70.37	66.80	54.94	96.41	99.66	156.24	122.60
Multiple-Cropped	13.26	12.78	15.49	15.75	18.07	18.44	20.31	9.21	6.41	6.33	7.91
Net Cropped	517.44	490.47	485.09	486.98	490.30	493.74	504.80	472.14	468.96	412.41	446.10

Figure20. Cropped and fallowed acres in Westlands Water District, 2000-2009
Source: Westlands Water District Crop Acreage Reports, 2000-2009. (WWD 2011c)

Note: There was a significant decline in total cropped acreage over the course of the drought, compared to pre-drought acreage, which remained relatively steady from 2000-2006.[31]

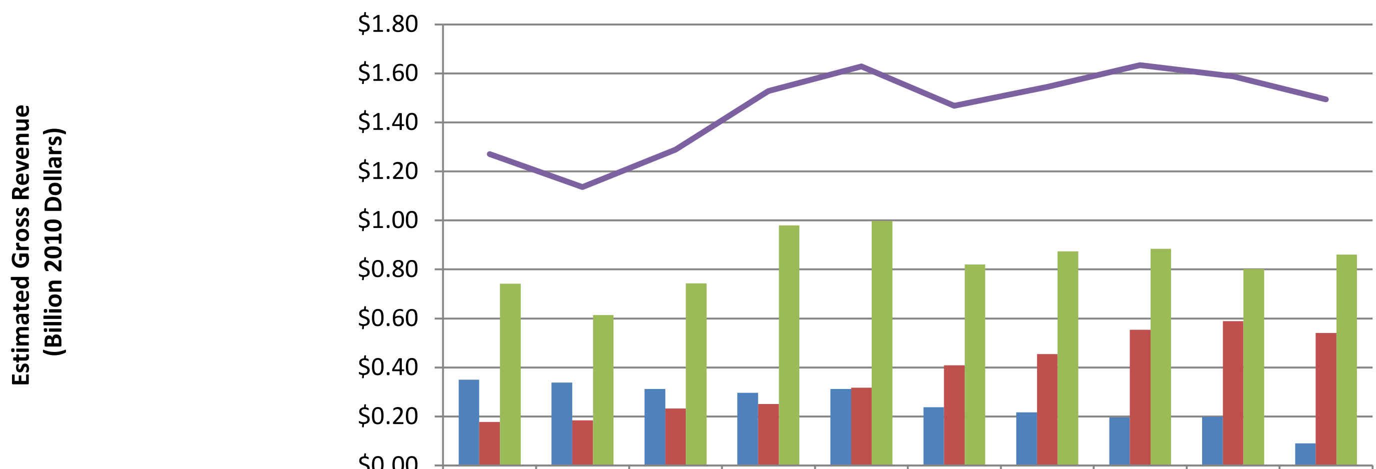
The value of crops produced at the district level is not available from the district crop reports themselves, and is estimated by combining district cropped acreage reports with relevant production value information available at the county level. Here, we use the district's crop acreage information and the production values from Fresno County crop reports to generate an approximation of crop value changes over the drought period compared to past years.[32] The results show that total production values by acreage peaked in 2007 and then slightly declined in 2008 and 2009. However, sharper declines were seen in 2001 and 2005, when there were no pumping restrictions in place, reflecting again the multitude of factors that affect agricultural production.

In 2007, the total value of Westlands's harvested acreage, in terms of estimated gross revenue from irrigated crops, reached an all-time high of $1.6 billion (see Figure 21). However, there was a significant decline in annual gross revenue in the district over the course of the drought (2007-2009), compared to the pre-drought period (2000-2006). Yet, the annual decrease in gross revenue between 2007 and 2009 parallels a significant annual increase in the estimated value per

[31] Total cropped acreage is the sum of net cropped (total acres minus fallowed acres) and double-cropped acreage. The slope of total cropped acreage versus time from 2000-2006 (pre-drought) and 2007-2009 (drought) was determined by ordinary least squares regression (95% confidence level), using annual total cropped acreage data. The best estimate slope from 2000-2006 was +320 ± 2,000 acres per year; from 2007-2009 the slope was -31,000 ±15,000 acres per year.

[32] Westlands serves both Fresno and Kings County, but the majority of the District is in Fresno County and there appears to be small differences and no across-the-board bias in annual crop values between the two counties. Therefore, we use only Fresno County crop production values to estimate Westlands' gross revenue.

AF applied water (or the economic productivity of water) over the same period.[33] During the drought, the economic productivity of water in Westlands was 30% higher than during the pre-drought period.



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Field and Seed Crop Acres	$0.35	$0.34	$0.31	$0.30	$0.31	$0.24	$0.22	$0.20	$0.20	$0.09
Fruit and Nut Crop Acres	$0.18	$0.18	$0.23	$0.25	$0.32	$0.41	$0.45	$0.55	$0.59	$0.54
Vegetable and Melon Crop Acres	$0.74	$0.61	$0.74	$0.98	$1.00	$0.82	$0.87	$0.88	$0.80	$0.86
Total	$1.27	$1.14	$1.29	$1.53	$1.63	$1.47	$1.55	$1.63	$1.59	$1.49

Figure 21. Estimated gross revenue, Westlands Water District, 2000-2009

Source: Westlands Water District Crop Acreage Reports, 2000-2009 and Fresno County Annual Crop Reports, years 2000-2009, Fresno County Agricultural Commissioner's Office. (Fresno County 2000-2009, WWD 2011c)

Note: Value is estimated by applying the calculated annual crop production value per acre, according to crop type, from Fresno County to annual harvested acreage of the same crop type in Westlands. This method is used because only acreage, not yield, is reported by the District. Although the District also serves a portion of Kings County, the majority of the District's land is in Fresno County. Values are in 2010 dollars adjusted for inflation.

[33] The slope of estimated gross revenue versus time and estimated revenue per acre-foot versus time, between 2000-2006 (pre-drought) and 2007-2009 (drought), was determined by ordinary least squares regression (95% confidence level), using estimated total annual values from crop production within Westlands Water District and estimated crop production value per AF (acre-foot) of applied water (values in 2010 dollars adjusted for inflation). For gross revenue, the best-estimate slope between 2000-2006 was +$65,000,000 ± $23,000,000 per year; between 2007-2009 the slope was -$70,000,000 ±$14,000,000 per year. For value per acre-foot, the best-estimate slope between 2000-2006 was +$51 ±$18 per acre-foot; between 2007-2009 the slope was +$175 ± $28 per acre-foot.

Economic Impacts

Estimating the economic impacts from the 2007-2009 drought is complex. Estimates depend on a variety of inter-related factors, including variability in crops, cropped acreage, production values, climate, weather, water availability, the state of the overall economy, international prices, and many more. These factors also make it difficult to establish a baseline recent “normal” year in terms of water supply and the economy for comparison, or to disaggregate among different influences. Due to lacking and/or inconsistent data across geographic regions and time periods, these many factors are difficult to interpret and synthesize, and only approximate estimates of actual economic impacts have thus far been made (see, for example, Michael et al. 2009). Here, we analyze the most recent empirical data from the USDA, county agricultural commissioners, irrigation districts, the U.S. Census, and the California Employment Development Department (EDD) in an attempt to quantify the actual, rather than modeled, economic changes experienced during the drought, and in comparison to the last decade.

Crop Insurance and Emergency Assistance

Farmers have access to emergency aid, loan, and insurance programs that in part cover farmer and rancher losses due to drought, floods, and other disasters. Farmers used these programs during the drought to supplement lost farm income due to drought-induced losses in crops and livestock.[34] The USDA provides various financial assistance programs, including the Farm Services Agency’s emergency farm loan program, the Supplemental Revenue Assistance Program that covers losses to agricultural producers in response to declared drought emergency events, and the Risk Management Agency’s crop insurance plans that cover drought and other disasters. Additionally, pursuant to the California Emergency Services Act, cities or county governments can proclaim an emergency and enable the use of additional emergency funds and resources. While agricultural-related disasters are quite common, with one-half to two-thirds of the counties in the United States designated as disaster areas in each of the past several years, impacts related to water shortages were a common theme in emergency proclamations and requests for assistance in 2007-2009 in California (DWR 2010).[35]

Crop insurance policies pay farmers for losses related to either below-average yields (crop yield insurance) or below-average revenue (revenue insurance) (see Table 13). With subsidies, most farmers pay around 40-50 percent of crop insurance premiums; in 2009, premiums for policies that protected against drought ranged between $178 and $185,635, with the average around $14,000.[36] During the drought, farmers were protected by both types of policies: yield insurance plans in the form of Actual Production History (APH) coverage, which protects against losses based on average, expected yields; and revenue insurance plans in the form of Crop Revenue

[34] We do not look at livestock and rangeland losses due to our focus primarily on water supply impacts to irrigated agriculture.

[35] For more information of the use of both the farm loan program and Emergency Services Act provisions during the drought by impacted counties, see DWR 2010.

[36] Private insurance companies sell crop insurance policies, but the USDA's Risk Management Agency (RMA) subsidizes the insurance premiums.

Coverage (CRC), which provides protection against gross revenue falling below a guaranteed level (USDA-ERS 2009).

Table 13: Comparison of yield- and revenue-type crop insurance policies covering drought losses in California (all counties), 2005-2009.

Year	Yield (APH)		Revenue (CRC)	
	Policies	Losses	Policies	Losses
2005	3	$7,198	1	$2,596
2006	37	$309,508	39	$530,155
2007	279	$2,265,335	49	$888,685
2008	212	$3,041,131	79	$2,278,495
2009	218	$4,416,506	123	$7,034,655

Source: USDA Risk Management Agency, Summary of Business with Month of Loss. Cause of Loss Historical Data Files. 2005-2009. (USDA-RMA 2011)

Note: APH is Actual Production History (yield) coverage, and CRC is of Crop Revenue Coverage. Numbers of policies and values are from all counties reporting losses due to drought (only). Values are in 2010 dollars adjusted for inflation.

In 2007, the majority of payments for drought losses were from yield (APH) policies (85% of policies, 73% of total payments); in 2008, a lesser majority of policies and payments were from yield (APH) coverage (73% of policies, 57% of payments); in 2009, while the majority of policies were still yield coverage (64%), the majority of payments were for revenue loss coverage (61%).

Table 14 summarizes California's drought-related agricultural losses compensated through the USDA Risk Management Agency crop insurance policies, totaling $20 million over the drought period.[37] The vast majority of drought-related crop insurance payments were made for field crops, primarily wheat, oats, and barley.[38] Half of the payments were made during the last year of the drought, indicating that impacts were becoming more severe as the drought persisted. In the final year of the drought, 2009, crop insurance payments in California totaled more than $11 million. Farmers and ranchers in the San Joaquin Valley counties took out the highest number of drought policies, and received the most in total payment for drought losses between 2007 and

[37] We include only payments for plans that cover "drought" losses, not payments for losses that may be related to the drought. Drought-only payments demonstrate the overall increase in drought payments made to farmers during the drought, and provides a comparison between counties. It does not provide a full and complete picture of total farm losses, nor the full amount of aid made available to farmers to cover those losses.

[38] Only in five cases during the drought period were crop insurance payments made for crops other than field crops. The following individual crop insurance policies and payments for fruit, nut, or vegetable crops include: a single payment of $49,071 for tomatoes in 2008 in Fresno County for; a single payment of $5,374 in 2009 for avocadoes in San Diego; a single payment of $27,930 in 2007 for prunes in Sutter County; and two single payments for $56,293 and $2,626 for walnuts in Calaveras and El Dorado Counties, respectively. These policies and payments are included in Table 14. The values given in this footnote are in the dollar amount reported the year in which they were claimed. These policies and payments are included in Table 14 (and adjusted to 2010 dollars in that table).

2009. In general, crop insurance payments to San Joaquin Valley counties increased each year of the drought. In comparison, Sacramento Valley crop insurance payments do not indicate increasing drought stress – a conclusion supported by available county agricultural data that show limited or no decreases in total acreage or yield during the drought years in those counties.

Table 14 also determines the average payment over the drought period for each policy. A farm may have more than one insurance policy, so this does not tell us the amount of payments to individual farms, which may have been higher. Nor do these data allow us to determine which farms received the payments. The USDA does not provide this information, and special legislation shields the identity of farms receiving government crop insurance from Freedom of Information Act requests. The data does give regional information.

Table 14: USDA drought-related crop insurance payments in California, 2005-2009

Region	County	Crop Insurance Payments					2007-2009		
		2005	2006	2007	2008	2009	Payments	Policies	Avg. Per Policy
San Joaquin Valley	Fresno	$0	$40,586	$581,274	$2,510,845	$6,910,363	$10,002,483	217	$115,837
	Kern	$0	$49,540	$135,959	$126,550	$295,752	$558,260	54	$35,298
	Kings	$0	$0	$361,821	$175,757	$424,948	$962,525	94	$34,780
	Madera	$0	$0	$229	$66,411	$9,715	$76,355	6	$26,547
	Merced	$0	$0	$0	$157,148	$397,122	$554,270	36	$29,387
	San Joaquin	$0	$0	$311,696	$359,799	$572,782	$1,244,277	51	$72,515
	Stanislaus	$0	$0	$10,154	$4,162	$31,286	$45,601	8	$19,530
	Tulare	$6,275	$7,874	$318,078	$445,319	$602,404	$1,365,801	132	$30,696
	TOTAL	**$6,275**	**$98,000**	**$1,719,211**	**$3,845,991**	**$9,244,370**	**$14,809,572**	**598**	**$364,589**
Sacramento Valley	Butte	$0	$0	$0	$967	$4,261	$5,228	2	$5,228
	Colusa	$0	$0	$21,058	$6,144	$139,527	$166,728	17	$22,998
	Glenn	$0	$0	$3,712	$0	$0	$3,712	1	$3,712
	Shasta	$0	$0	$747	$0	$0	$747	1	$747
	Solano	$0	$0	$138,767	$98,860	$0	$237,627	16	$30,353
	Sutter	$0	$0	$29,373	$17,271	$0	$46,644	2	$46,644
	Yolo	$0	$0	$30,311	$25,609	$6,731	$62,651	18	$10,355
	TOTAL	**$0**	**$0**	**$223,968**	**$148,851**	**$150,519**	**508026**	**57**	**$120,038**
Southern California	Imperial	$0	$0	$0	$0	$0	$0	0	$0
	Los Angeles	$0	$0	$9,648	$981	$0	$10,629	5	$3,393
	Riverside	$0	$693,765	$954,770	$875,046	$1,507,293	$3,337,109	156	$63,327
	San Diego	$0	$45,747	$51,379	$32,955	$5,462	$89,796	3	$89,796
	TOTAL	**$0**	**$739,512**	**$1,015,797**	**$908,983**	**$1,512,755**	**$3,437,535**	**164**	**$156,517**
Central Coast	Monterey	$518	$2,151	$20,895	$2,155	$50,957	$74,007	11	$30,246
	San Benito	$0	$0	$16,959	$12,769	$19,968	$49,697	16	$9,969
	San Luis Obispo	$0	$0	$217,854	$335,214	$418,167	$971,235	90	$35,739
	TOTAL	**$518**	**$2,151**	**$255,708**	**$350,138**	**$489,093**	**$1,094,939**	**117**	**$75,953**
Other	Alameda	$0	$0	$3,549	$24,337	$0	$27,887	6	$8,417
	Calaveras	$0	$0	$0	$0	$57,216	$57,216	1	$57,216
	El Dorado	$0	$0	$0	$0	$2,669	$2,669	1	$2,669
	Modoc	$2,596	$0	$0	$0	$0	$0	0	$0
	Placer	$0	$0	$0	$30,072	$0	$30,072	5	$6,014
	Sonoma	$405	$0	$0	$11,254	$0	$11,254	2	$5,627
	TOTAL	**$3,001**	**$0**	**$3,549**	**$65,663**	**$59,885**	**$129,098**	**15**	**$79,943**
All Regions	**All Counties**	**$9,794**	**$839,663**	**$3,218,233**	**$5,319,626**	**$11,456,622**	**$19,994,481**	**951**	**$27,484**

Source: USDA Risk Management Agency. Cause of Loss Historical Data Files: Summary of Business with Month of Loss. 2005-2009. (USDA-RMA 2011)

Note: Table includes annual crop insurance payments made to agricultural producers for "drought" losses only. The average per-policy payment amounts for counties are annually weighted averages. This table includes all drought-impacted counties reporting "drought" losses in California between 2005 and 2009. Payments are in dollar amounts reported for that year.

Fresno County farmers and ranchers received the highest total drought-period insurance payments compared to other counties. On average, Fresno policyholders received almost $80,000 more per policy than neighboring county policyholders. Over 200 drought insurance policies were paid in Fresno County during the drought, totaling $10 million. While Fresno stands as the largest recipient of drought aid in the form of crop insurance payments, Fresno County's agricultural production data does not indicate that Fresno lost more than other counties. County crop data shows that while Fresno's harvested acreage was down in 2007 and 2009, county production values and yields of top revenue-generating crops were higher than, or equal to, previous years.

Neighboring Kern County appears to have suffered greater economic harm during the drought years in terms of reduced production of top-grossing crops; however Kern received $9.3 million less in crop total crop insurance, and $87,000 less per policy on average, than Fresno County during the drought. These data indicate that federally-subsidized crop insurance may not actually be providing an economic buffer to those areas most affected by drought in California. We note that crop insurance payments tell only a small part of the story. Drought insurance policies were not the only form of aid available to farmers during the drought, and other drought-related losses may have been captured by other types of policies not explicitly tied to "drought."

Employment and Poverty

The San Joaquin Valley is among the regions in the United States with the highest rates of unemployment and poverty, and has been particularly hard hit by the foreclosure crisis that led to the national and global recession. In the political debate surrounding water, there have been many claims that water restrictions are behind the region's high unemployment. For instance, local media covered Fox News personality, Sean Hannity, as he made several trips to the San Joaquin Valley during 2009. A particularly dramatic article in the *Hanford Sentinel* described Hannity "perched atop a stage surrounded by a large crowd of local supporters, lambasted the federal government for cutting back delta pumping to the Westside to preserve a '2-inch minnow'…People who gathered for the event booed lustily as Hannity held up a giant photo of the fish" (Nidever 2009). A more restrained piece in the *Fresno Bee* reported that "several thousand people cheered him [Hannity] as he made fun of 'radical environmentalists,' saying they are protecting the delta smelt over the needs of farmers and their workers" (Sheehan 2009).

In this section, we demonstrate that while unemployment increased within the Valley and statewide over the drought period, job losses were concentrated in sectors not related to agriculture. In fact, the proportion of agricultural jobs has either remained stable or increased in areas facing the greatest reductions in federal and state water deliveries. This finding directly contradicts claims that water shortages caused agricultural job losses. Moreover, the drought played an important role in highlighting the very real and chronic poverty in the San Joaquin Valley, yet did little to address long-term structural challenges, such as inequitable wages in the region (Page et al. 2005), the seasonality of many agricultural jobs,[39] and the high percentage of undocumented agricultural workers.[40]

It is very difficult to ascertain who lost jobs during the drought. However, recently released U.S. Census data allows one to examine employment trends from 2006-2009 at a fairly fine scale using Public Use Microdata Areas (PUMAs) (see Figure 22).[41] In the case of Fresno County, the Census Bureau divides the county up into four geographical areas; PUMA 03401 covers the west side of Fresno County, which experienced sharp cutbacks as lower priority federal water project contractors. These data are helpful in improving our understanding of local employment trends.

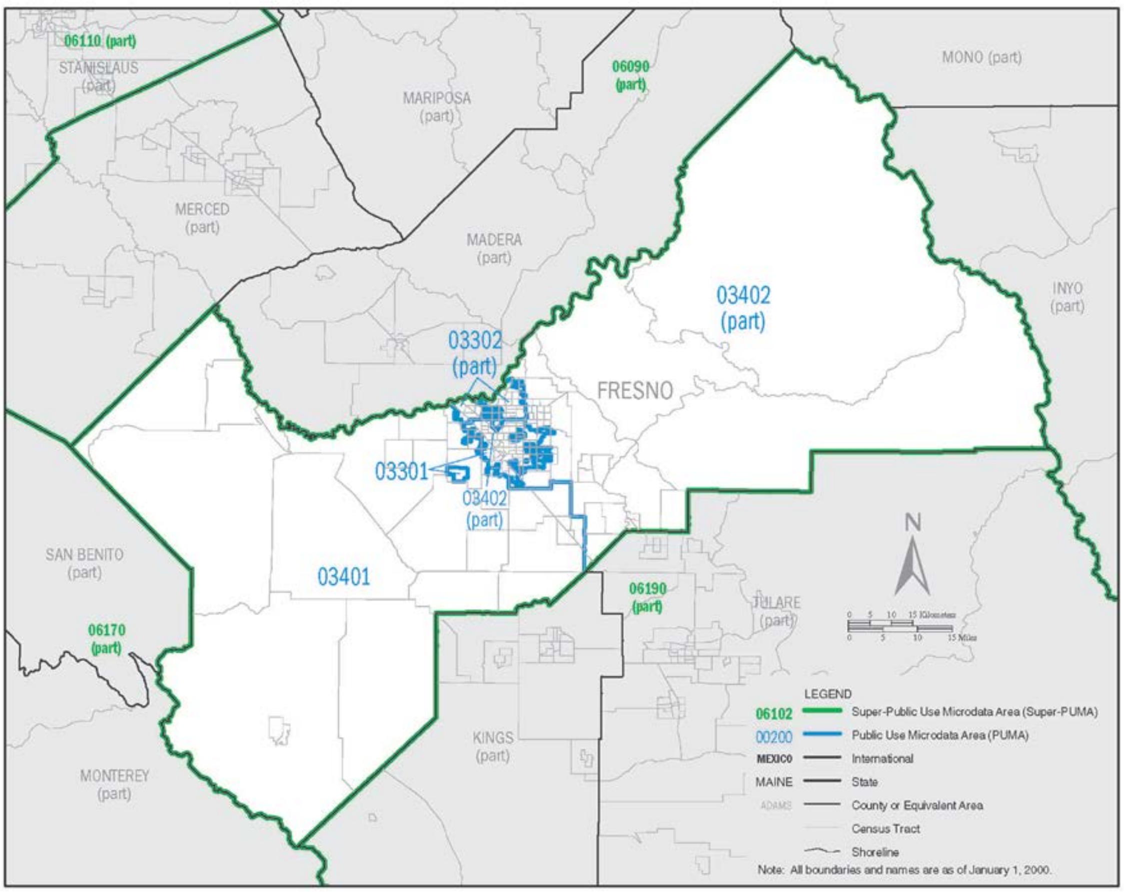


Figure 22. Fresno County's Public Use Microdata Areas

Source: California Super-PUMA 06180: U.S. Census 2000 Public Use Microdata Areas (PUMAs), Fresno County. (US Census Bureau 2000)

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[39] The average farm worker works 6 months a year according to the National Agricultural Worker Survey.

[40] Around 50% of farm workers in California are undocumented, according to the 2005 Bureau of Labor Statistics.

[41] This PUMA data compiles 2009 American Community Survey 1-Year Estimates. Due to sampling protocols, the data may underestimate the unemployment rate among undocumented workers.

Data from the west side of Fresno County demonstrate a statistically significant growth in agriculture-related jobs (7%) as a proportion of total jobs available and statistically significant declines in the proportion of jobs in sales and office occupations (-5%) and construction and maintenance occupations (-3%). Compared to all other sectors, farming, fishing, and forestry occupations increased the most as a portion of the total jobs available.

This does not mean that jobs were not lost in this sector, as the total number of jobs decreased in 2008. It simply means that agriculture-related jobs remained a high proportion of the total jobs available. In addition, the data does not provide demographic information about who lost jobs. Yet, the data strongly suggest that the farming, fishing, and forestry occupations were more robust than many other sectors.

The east side of Fresno County (PUMA 03402) reported a 3% decline in total employment but no statistically significant changes in the proportion of jobs in different occupational sectors over the drought-period. In Kings County (PUMA 03600), overall employment declined by 1% with a statistically significant decline in the proportion of construction-related occupations (-3.5%). Again, farming, fishing, and forestry occupations remain a relatively strong sector, reporting a slight, though not statistically significant, increase as a proportion of total jobs (2%). In Kern County (PUMAs 03901 and 03902) total employment declined by 1%, but the proportion of jobs in farming, fishing, and forestry remained the same from 2006 to 2009. Finally, in Tulare County (PUMA 03503) reported a 1% decline in total employment but no statistically significant changes in the proportion of jobs in different occupational sectors over the drought-period. In order to gain a better understanding of the impacts of the drought on employment statewide, a larger and more in-depth study is warranted. However, these data do not indicate that agriculture-related jobs were disproportionately reduced during the drought in areas directly impacted by water supply restrictions.

The drought period coincided with the foreclosure crisis and a national and global recession. From 2005 to 2009, unemployment almost doubled statewide from 5.4% to 11.3%.[42] Michael et al. (2010) found that over the same time period crop production and agricultural support jobs declined by 1.5% (2,500 jobs) to 2.3 % (3,750 jobs) in the San Joaquin Valley. The U.S. Census data, however, indicates that many employment sectors saw far greater declines than farming, fishing, and forestry occupations, which either remained stable or increased as a portion of the total jobs available in areas directly affected by water supply reductions. These conclusions are strengthened by EDD data, which finds that over a longer time period (2003-2009) agricultural employment throughout the Central Valley gained slightly (2%) while natural resources, mining, and construction jobs fell by 44% and employment in the trade, transportation, and utilities sectors fell by 46% (see Figure 23).

[42] Statewide unemployment rates are calculated by California's Employment Development Department and are available here: http://www.labormarketinfo.edd.ca.gov/?pageid=164

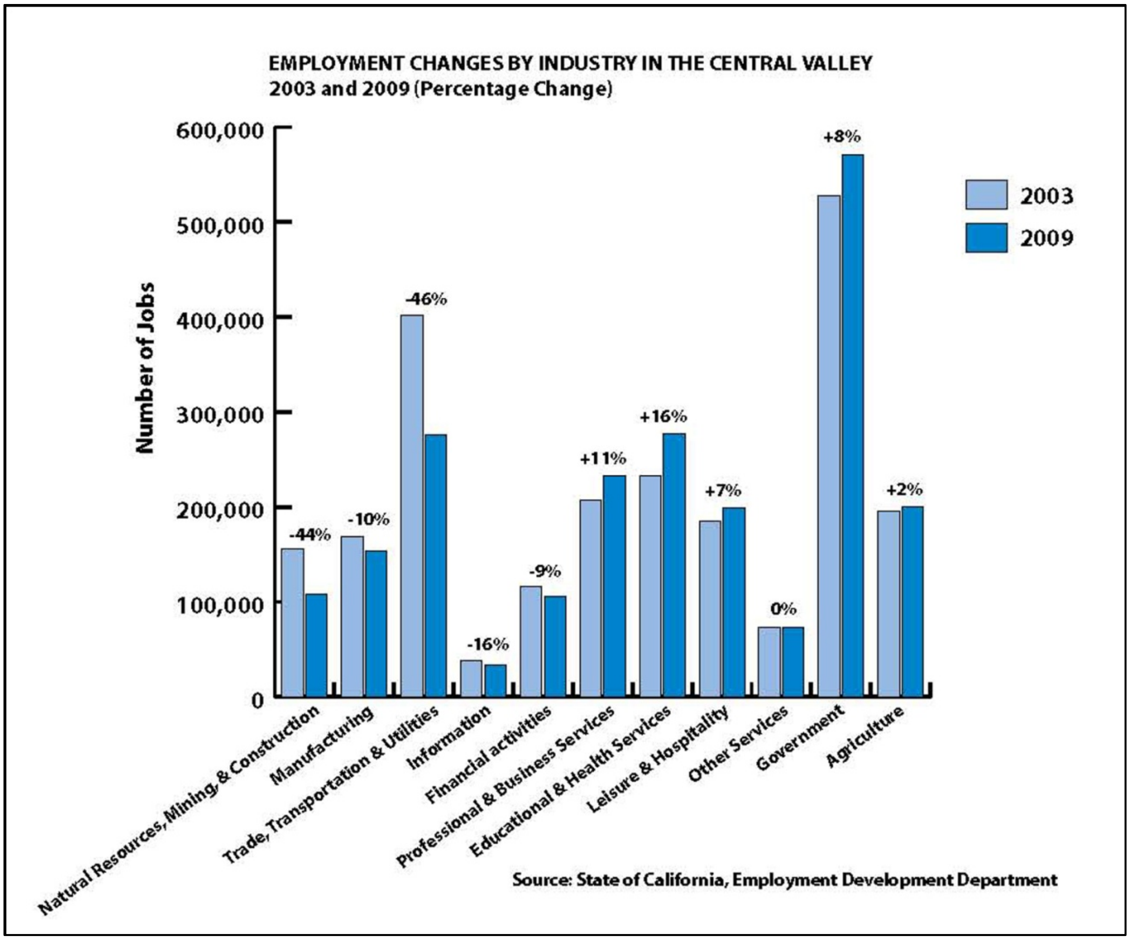
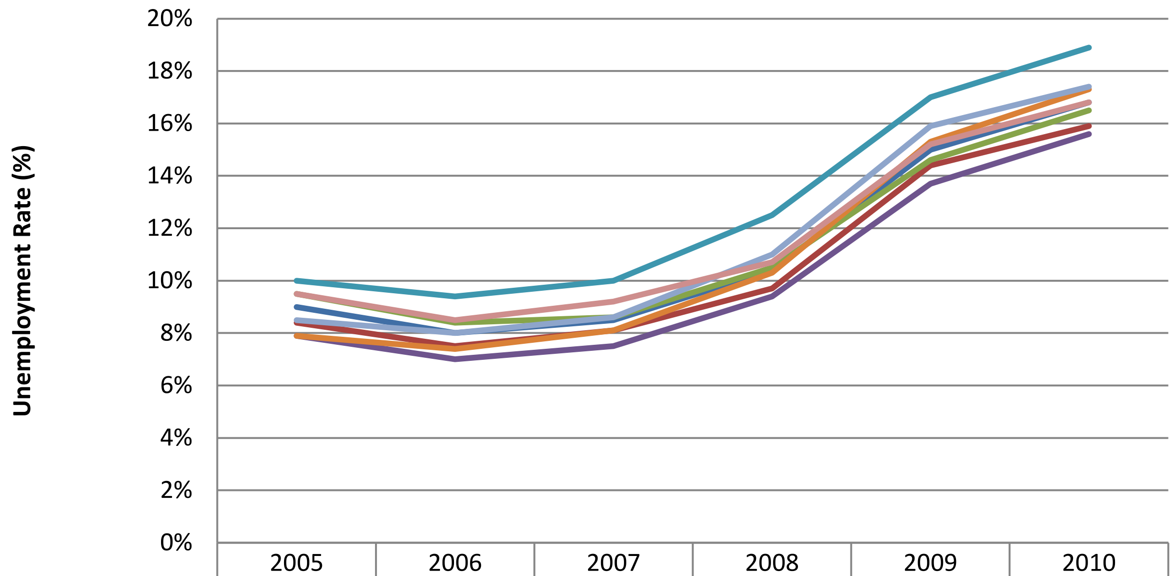


Figure 23. Employment changes by industry in the Central Valley in 2003 and 2009
Source: Originally published in *The State of the Great Central Valley of California.* (Moffatt 2009)

While water may have played a role in some areas, any discussion of unemployment rates must take an historical perspective. The San Joaquin Valley has had much higher levels of unemployment than the state or nation over the past 20 years (Cowan 2005). And as further evidence that fluctuations in water availability have little apparent impact on jobs, new data show that 2010 unemployment rates exceeded 2009 levels in all San Joaquin Valley Counties, despite the fact that water availability was significantly greater in 2010 (see Figure 24).



	2005	2006	2007	2008	2009	2010
Fresno	9%	8%	9%	10%	15%	17%
Kern	8%	8%	8%	10%	14%	16%
Kings	10%	8%	9%	11%	15%	17%
Madera	8%	7%	8%	9%	14%	16%
Merced	10%	9%	10%	13%	17%	19%
San Joaquin	8%	7%	8%	10%	15%	17%
Stanislaus	9%	8%	9%	11%	16%	17%
Tulare	10%	9%	9%	11%	15%	17%

Figure 24. Annual unemployment rates by Central Valley county, 2005-2010
Source: California Employment Development Department. (EDD 2011)

Finally, there have been many references to unemployment rates in the struggling communities in and around the Westlands Water District. Unemployment and poverty is indeed shockingly high in this area, and has been for years. The 2000 Census, taken during a time of good water supplies, found unemployment in Mendota was 30%, the highest rate of any California town, and among the highest unemployment rates in the nation (Cowan 2005).[43]

Since reliable unemployment estimates for these small areas are only available at 10-year Census intervals, it is illuminating to observe unemployment trends in Census tracts around the Westlands Water District since they began receiving CVP water from the Delta in 1968. Table 15 clearly shows that unemployment has been steadily increasing since the CVP brought surface water supplies to the region. A California Institute for Rural Studies report discusses this trend and links it to federal subsidies and a lack of enforcement of the Reclamation Reform Act that

[43] Census data is collected every ten years in the early spring, before many seasonal workers are hired, and therefore reflects off-season employment rates.

allows a few large farm operations to reap most of the benefits of federally subsidized irrigation projects in the region (Villarejo and Redmond 1988).

Table 15. Historic unemployment rates on the west side of Fresno County

Census Tract	1960	1970	1980	1990	2000
San Joaquin - Tranquility	5.58%	5.82%	9.13%	19.05%	23.89%
Mendota	9.99%	10.67%	21.00%	20.12%	29.88%
Firebaugh	2.29%	9.76%	12.79%	15.22%	21.84%

Source: Historical Census data from the National Historic Geographic Information System, Census tracts include both cities and the rural area surrounding them (NHGIS 2011)

Statewide, the average poverty rate is around 13%, however in the San Joaquin Valley, rates are closer to 20% (Kolko 2009), and have remained high in both wet and dry years. Recent attention during the drought to the human suffering in this region has been useful in terms of highlighting severe and chronic poverty, but communities within the San Joaquin Valley have been suffering for decades: "Socioeconomic conditions in the SJV [San Joaquin Valley] as measured by a range of variables (including per capita income, poverty, unemployment rates, median household income, Medicaid and Food Stamp participation rates, and sources of personal income) reveal an area that falls significantly below national and California averages" (Cowan 2005). Policies to improve conditions in the area should focus on identifying and addressing the factors that have led to long-term economic hardship in the region.

A study from the University of California at Davis Center for Public Policy examining unemployment, median wage, and wage dispersion in California over almost 30 years (1977-2004) concludes that: "Relatively little of California's upward trend in poverty can be explained by rises in the unemployment rate alone…Most of the increase in California's poverty rate can be explained by changes in wage inequality" (Page and Stephens 2005). Thus, genuine efforts to address chronic poverty in the region would likely focus on the widening gap in wages, the seasonality of agricultural employment, the undocumented status of much of the agricultural workforce, and other long-term structural problems that have contributed to sustained, high rates of poverty for many years rather than solely focusing on agricultural water supplies.

Impacts to the Environment

California's long history of human impacts on the natural environment has increased ecosystem vulnerability to extreme droughts. In many cases, the recent drought exacerbated long-term declines, particularly in the case of aquatic and riparian resources. We discuss trends that were exacerbated by the 2007-2009 California drought, where supporting information is available. We have not attempted to establish a quantitative baseline for ecological impacts because it is not possible to disaggregate the effects of pollution, overexploitation, habitat destruction, and introduced species. Nor is it possible to assess ecological impacts in their entirety. In addition, scientists do not discover most changes in ecological systems until long after they have occurred, and it is impossible to study whole ecosystems comprehensively. Consequently, scientists and policymakers alike must rely on indicators of ecological health. A final problem is that ecological impacts cannot be easily or adequately quantified in economic terms, making it difficult to equate and compare impacts across sectors. Although we provide some economic information for fisheries where it is available, most comparisons across sectors are necessarily qualitative.

While there are many ways to analyze impacts on the environment, below we focus on changes in: the salinity of the Sacramento-San Joaquin Delta, the volume of environmental flows for waterfowl and wildlife refuges, and the health of fisheries during the drought years. These metrics have been consistently tracked over the years, allowing us to examine long-term and drought-period trends. Our review of these data indicate that among the consequences of the 2007-2009 drought were increased salinity, reductions in flows for waterfowl and wildlife refuges, and catastrophic declines in many fisheries.

Salinity

The salinity of the Delta varies depending on the volume of freshwater inflows and on tidal conditions. The drought reduced the amount of freshwater flowing to the Delta from rivers and streams, resulting in greater saltwater intrusion to freshwater regions of the Delta. Saltier water can negatively impact estuarine species, drinking water, and irrigation water supplies.

Prior to the drought, the Delta was already experiencing salinity problems. Reductions in the Delta's freshwater flows and changes in the variability of fresh and saline conditions are largely due to upstream and in-Delta diversions and water exports that reduce the amount of freshwater moving through the Delta, and to regional climate change. Studies and salinity measurements confirm that Delta salinity is now at or above the highest salinity levels found in the past 2,500-to-4,000 years (CCWD 2010). Under equivalent hydrological conditions, the boundary between salt and fresh water is now 3-to-15 miles farther into the Delta than it would have been without the increased diversions of freshwater that have taken place in the past 150 years (CCWD 2010).

The reductions of freshwater inflows into the Bay Delta – historically and during the drought – have altered the location of the entrapment zone, a critical mixing zone where nutrients, phytoplankton, zooplankton, and fish larvae and eggs accumulate. The entrapment zone is critical to the overall health and ecological productivity of the estuary. The entrapment zone, depending on the volume of flows, moves from the outer to inner bay – with low flows, it can move upstream into the lower Sacramento River. As the entrapment zone moves farther upstream, it reduces the overall abundance of plankton, the base of the estuary's food web (Williams 1989, Arthur and Ball 1979). Scientists have noted a statistically significant relationship between the survival of juvenile Delta smelt (an endangered Delta fish species) and plankton biomass from 1972 to 2005 (Baxter et al. 2008). Baxter et al. (2008) find that bottom-up food limitation, or the availability of plankton as food for fish, corresponds to fish population size (Baxter et al. 2008). It is significant that salinity levels in the Delta negatively impact the base of the estuary food chain: plankton and Delta smelt population sizes serve as indicators of the health of the larger Bay Delta ecosystem.

During drought years, salinity levels in the Delta reached record high levels, particularly during dry summer months, when the least amount of freshwater is available to the Delta. Salinities in Suisun Marsh (the tidal marsh connecting the Delta and the San Francisco Bay) are strongly inversely correlated with Delta outflow to the Bay (O'Rear et al. 2008). During the drought, average monthly salinities were high, reflecting the low Delta outflow (which in turn stemmed from low inflows to the Delta from freshwater rivers and streams). The average annual salinity for 2008 was the saltiest recorded since 1992 (see Figure 25): "Average monthly salinities in 2008 were considerably higher than that for the all-year (1980-2009) averages for much of spring, all of summer, and early autumn…Similar to 2008, the average monthly salinities in 2009 were higher than the average for all years except in March and May" (O'Rear and Moyle 2010, p. 30).

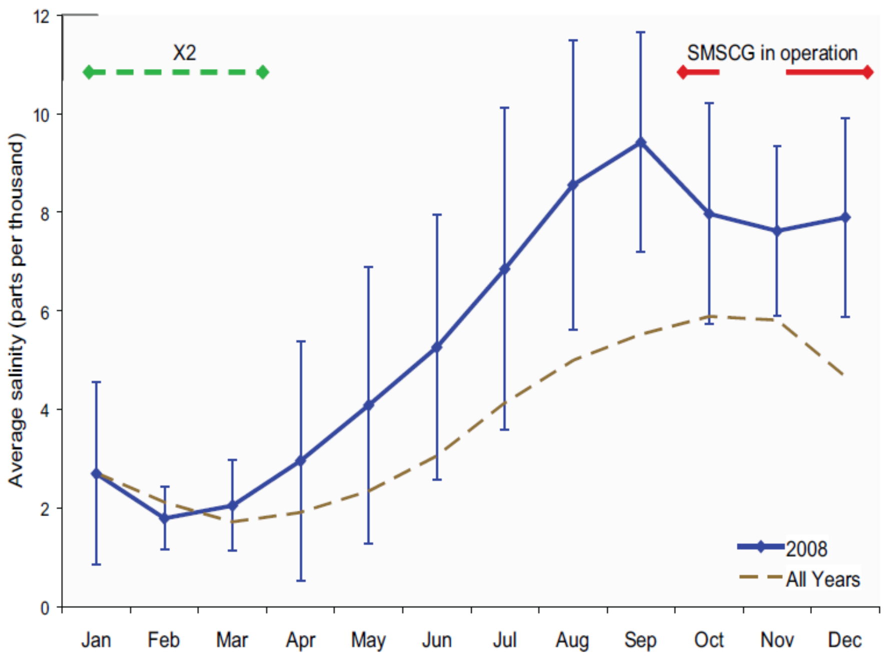


Figure 25. Average monthly salinities for 2008 and from 1980 to 2009 ("all years"), with timing of important events. Error bars are standard deviations for 2008.
Source: O'Rear and Moyle 2010

Note: The location of "X2" is the distance in kilometers from the Golden Gate Bridge (seawater) to water with salinity of 2 parts-per-thousand or less (freshwater). The X2 distance is associated with the highly productive entrapment zone (Jassby et al. 1995; Kimmerer 2004). Consequently, when X2 is located in Suisun Bay, the abundance of fishes in Suisun Marsh is often relatively high. X2 was located in Suisun Marsh for 23% of 2008, with those days occurring in winter and early spring before the youngest fishes had hatched or migrated to the marsh. Consequently, few marsh larvae or juveniles were likely to have benefited from conditions often associated with X2 in 2008. In addition, it is important to note that the Suisun Marsh Salinity Control Gates (SMSCG) went into operation from October 2-14, the latter half of November, and most of December, noticeably reducing salinities in the marsh.

Higher levels of salt in Delta waters can also impact farming operations, particularly in the Delta but also for south-of–the-Delta water users. Much of the state's drinking water also comes from the Delta. Saltier water may increase the need for treatment, which has direct energy impacts. Higher energy consumption for water treatment can increase greenhouse gas emissions. (See Impacts to Energy for a discussion of direct energy impacts of the recent drought.)

Waterfowl and Wildlife Refuges

During the drought, environmental flows, most often protected under state and federal legislation, decreased. As flow objectives protect and sustain aquatic species, unmet flow requirements during the drought further threatened the health of those species. Stream flow quantity and timing, the principle components of the environmental flow objectives discussed here, are critical to the ecological health of river systems, as stream flows are linked to water temperature, channel geomorphology, habitat diversity, and ultimately, the abundance and diversity of aquatic species (Poff et al. 1997, Resh et al. 1988). Modifications of a river's natural flow regimes can have cascading negative effects on the integrity of riverine habitats (Poff et al. 1997). Components of a natural flow regime can be mimicked by setting flow objectives that require certain flows at certain times. Environmental flow objectives can be targeted to specific seasons, months, and even weeks or days, when certain species of fish are migrating through a given river system (see Table 16). Not meeting flow objectives during those times can greatly reduce chances for survival. Re-established environmental flows maintain riverine ecosystem processes by supporting channel flows, temperatures, and riparian vegetation corridors, thereby maintaining aquatic species (Rosekrans and Hayden 2003).

Table 16. Range of environmental flow objectives for four California river systems (at particular flow gauging stations)

Flow objectives	American (Nimbus)	Stanislaus (Goodwin)	Trinity (Lewiston)	San Joaquin River (Vernalis)
Winter minimum flow or flow range *	500 cfs – 2,500 cfs (1 - 5 TAF/day)	200 cfs – 300 cfs (0.4 - 0.6 TAF/day)	300 cfs (0.6 TAF/day)	710 cfs - 2,000 cfs (1.4 - 4 TAF/day)
Spring minimum flow or flow range *	2,000 cfs - 4,500 cfs (4 - 9 TAF/day)	1,500 cfs (3 TAF/day)	1,500 cfs - 8,500 cfs (3 - 17 TAF/day)	3,110 cfs - 7,330 cfs (6 - 14.5 TAF/day)

Source: Daily average flows (in cfs) are generated from DWR's California Data Exchange Center (CDEC) (stations listed in table) (DWR CDEC 2011). Flow objectives for the American and Stanislaus Rivers are found in the Anadromous Fish Restoration Program, 2001; Trinity River requirements are found in the Trinity River Record of Decision, 2000; and San Joaquin River requirements are found in the 1995 Water Quality Control Plan.

*Notes: *Flow objectives (in cfs) vary daily, weekly and/or monthly. The range of flow objectives represents the range between the lowest and highest flow requirement during the entire spring or winter period, as identified in the documents cited above. Spring and winter flow requirements take into account available flows during a specific time period (days, weeks, or months), for a specific river system, and species' needs during those time-periods.*

Table 17. Unmet volume of annual flows in thousands of acre-feet (TAF) according to above target flows (Table 16)

Year	American (Nimbus)	Stanislaus (Goodwin)	Trinity (Lewiston)	San Joaquin River (Vernalis)
1998 (Wet)	25	7	109	0.8
2000 (Normal)	55	34	72	6
2001 (Dry)	81	0	79	19
2006 (Wet)	36	4	0	0.2
2007 (Dry)	63	36	0	60
2008 (Critically Dry)	319	28	3	48
2009 (Dry)	286	53	5	204

Source: Unmet flow levels are determined by matching recorded flows with environmental flow requirements from the documents listed above. Flow objectives are met according to a calculation of the difference between actual and required flows (cubic feet per second); unmet flow objectives are totaled and converted to volume of unmet flows.

Note: These calculations reflect a lower bound of the volume of unmet annual environmental flows. Where source documents gave multiple potential flow requirements (lesser or greater, depending on various operational and environmental criteria) we chose the lowest flow requirement provided for the respective water year. These calculations are meant to demonstrate trends over time in unmet flow objectives. From year to year, there are individual adjustments and exceptions made in the amount of flows needed or required in a given river system, and these calculations do not reflect those adjustments.

Legislation and various state and federal collaborations established environmental water requirements centered on the Bay Delta ecosystem beginning in the 1990s. Today, three primary requirements fall under the CALFED[44] Programmatic Record of Decision (CALFED 2000): the

[44] CALFED is a state and federal agency effort initiated in the 1990s to improve California's water supply and the ecological health of the San Francisco Bay and Sacramento-San Joaquin River Delta. The CALFED Bay Delta Program's 2000 programmatic Record of Decision (ROD) laid out a science-based planning process for Delta improvements,. The California Bay-Delta Authority was created in 2002 to oversee the program's implementation, and Congress adopted the plan in 2004 (CALFED Bay Delta Program 2011. http://calwater.ca.gov/).

Central Valley Project Improvement Act (CVPIA); the Water Quality Control Plan (WQCP); and the Environmental Water Account (EWA). Each is described briefly below.

The CVPIA water legislation was passed by Congress in 1992, mandating changes in management of the CVP for the protection, restoration, and enhancement of fish and wildlife in the Central Valley and Bay Delta (USBR-MP 2011c). Long-term (25-year) water supply agreements facilitated through the CVPIA provide water to private, state, and national wetland and wildlife areas (USBR-MP 2011c). The Act established supplies of water dedicated to the environment, either through project operation criteria, dedicated volumes of water (flow requirements), or funding for flow purchases. In direct response to water-quality problems in the Bay Delta, federal and state agencies, water contractors, and environmentalists negotiated the Bay Delta Accord in 1994, whose standards became the WQCP. The WQCP places limits on state and federal exports from the Delta according to fish life cycle needs and the impact of flows on salinity during different times of the year.

Finally, the EWA was established as part of the CALFED Plan in 2000. The account purchases water and distributes supplies according to what was intended to be an adaptive, real-time management strategy that would benefit aquatic species in the Bay Delta. The three programs are separate, but also interlinked. For example, the EWA was envisioned as a key component to achieve CALFED goals, and WQCP goals are partially met with the use of CVPIA (B2 account) water and are managed under CALFED.

According to the DWR, state and federal Central Valley wildlife refuges covered under the CVPIA received all of the CVP water to which they were entitled in 2007-2009. USBR “Level 2” refuge supplies made up approximately 71% of the water needed by refuges pursuant to the CVPIA; the USBR (under direction of the CVPIA) purchased remaining needed water for wildlife refuges – “Level 4” supplies (DWR 2010). However, the CVPIA requirements do not represent the full palate of environmental protections established to maintain healthy aquatic ecosystems in the state as a whole. There are numerous environmental flow objectives that have gone unmet for years (Rosekrans and Hayden 2003). Guarantees for environmental water requirements envisioned through CALFED have fallen short: a complicated history of operational adjustments, administration and recordkeeping, Interior Department decisions, and court rulings resulted in a diminishing volume of water supplies dedicated to environmental services from 2000 onward. For a complete analysis of CALFED’s CVPIA and EWA shortfalls in the 2000s, see the Environmental Defense Fund’s (EDF) “Finding the Water” report (Rosekrans and Hayden 2005).

Unmet objectives are hard to accurately gauge due to significant data gaps and the lack of a total assessment of unmet environmental objectives throughout the state. Nevertheless, EDF estimates – based on an analysis of water operations data in recent years – that California’s environmental flow objectives in the Bay Delta region alone have been shorted by approximately 420,000-460,000 acre-feet of water annually (Rosekrans and Hayden 2005) . Total unmet objectives for the entire state are likely larger. Yet again, disparate and incomplete data collection and assessment of flow requirements make complete assessment impossible.

Table 17 above demonstrates that there are on-going problems meeting environmental flow objectives in many California river systems, which, in many cases the drought exacerbated. For example, the average quantity of unmet flows in 2008 and 2009 in the American River below Nimbus dam was nearly four times greater than in the pre-drought dry year of 2001, and eight times greater than the wet year of 2006. During the 2008 critically dry water year, flow objectives for the American River were not met for eight consecutive months. In the 2009 dry water year, Stanislaus River flows were under the minimum required for four-and-a-half consecutive months beginning in November, 2008; overall, average drought period unmet flows were 10 times higher than in the preceding wet year of 2006. In the San Joaquin River, average unmet flows over the drought period were five times higher than in dry year 2001, and more than 500 times the quantity of unmet flows in 2006. In 2009, San Joaquin River flow objectives went unmet 67% of the time[45] and between March 15th and May 15th of that year, flow objectives were met on only five days[46]. The Trinity River in the north was one river system that does not appear to have experienced increases in unmet flows during the drought period.

Wet year flow objective deficits can actually be higher than dry year flow deficits because wet year requirements can be substantially greater in flow, and therefore total volume, than dry year flow requirements, on a monthly, weekly, or even daily basis. For example, flow requirements below Lewiston Dam on Trinity River during the second half of May range from 5,000-8,500 cfs during wet years, while during dry years, requirements range from 1,400-2,900 cfs. Although both wet and dry years saw environmental flow deficits during the second half of May, wet year deficits were greater relative to the wet year requirement. This does not necessarily mean that aquatic species suffered more in wet years due to unmet flow objectives. It is likely that dry year environmental flow deficits, although smaller, were more harmful due to greater overall decreases in flows and related increase in stream temperatures.

Other tools to protect environmental flows have proven relatively ineffective and unenforceable. The Environmental Water Account (EWA) was adopted in 2000 as an innovative water management tool intended to protect endangered fish in the Delta from the harmful operational impacts of the federal and state water projects. The EWA was intended to allow the state and federal agencies to buy water for the environment without reducing existing water supply or deliveries from the Delta. According to EDF (Rosekrans and Hayden 2005, p. 12), “The EWA has had significantly less water than expected to do its job…Unfortunately, due to a combination of insufficient operational assets and dwindling funding, early on the EWA was effectively robbed of some of its potential.” The EWA has been most successful in its procurement and distribution of purchased water. However, this depends on funding received by the EWA, which was already diminishing prior to the drought due to the worsened state of California’s ongoing budget crisis. The state’s current economic crisis, combined with surplus reduced water availability due to drought, limits the extent to which water purchases can be made, and thereby limits the ability of a program like the EWA to serve the environment.

Ultimately, many environmental flow objectives were unmet, and therefore did not adequately provide for, or protect, riverine ecosystems during the drought.

[45] Objectives were not met 60 days out of a total of 181 days for which there are flow objectives.

[46] In comparison, in 2007 and 2008, flow objectives in the San Joaquin were met just over 75% of the time.

Fisheries

Freshwater flow conditions affect the health of freshwater and anadromous fish species (species that migrate from salt water to spawn in freshwater). Drought can act as an additional stressor for a population already experiencing long-term declines, driven by multiple factors including over-fishing, poor ocean conditions, reduced food availability, loss of habitat, predation, competition from introduced species, and water quality degradation. Even if it is not completely clear what role drought alone plays in the context of California's complex and highly managed freshwater ecosystems (DWR 2010), evidence demonstrates a direct relationship between reduced flows, higher in-stream temperatures, and resulting declines in important fisheries (Gleick and Nash 1991).

Critically important to many of California's fish species is the San Francisco Bay – one of the world's largest estuaries. The Bay Delta system drains nearly 60,000 square miles of California watershed, and is the hub not only of the state's water supply for humans, but also provides habitat for 700 native plant and animal species. Two-thirds of the state's salmon and more than a million waterfowl and shorebirds migrate annually through the Delta and along the Pacific Flyway. Native delta fish species include Delta smelt, longfin smelt, Sacramento splittail, steelhead trout, four different runs of Chinook salmon (Central Valley fall-, late fall-, and spring-run, and Sacramento River winter-run), and sturgeon.

Yet, many of the Delta's fisheries are in crisis – and were in danger even before the drought (see Table 18). Under the federal ESA a species is considered "endangered" if it is at risk for extinction throughout all or a significant portion of its range, and "threatened" if the species is likely to become endangered in the foreseeable future (NOAA 2010). The California state ESA serves a similar purpose, with a focus on protecting species native to California.

Table 18. Protected anadromous fish species native to the Sacramento-San Joaquin Delta watershed

Fish Species	CA State Listing (CESA)	Federal Listing (ESA)	First Year Listed
Delta smelt	Endangered (2010)	Threatened	1993
Longfin smelt	Threatened	Under Review	2010
Central Valley spring-run Chinook salmon	Threatened	Threatened	1999
Sacramento River winter-run Chinook salmon	Endangered	Endangered	1994
Central California coast coho salmon	Endangered (2005)	Threatened	1996
Green Sturgeon	Threatened	Threatened	2006
Central California coast steelhead trout	Threatened	Threatened	1997
California Central Valley steelhead	Threatened	Threatened	1998

Source: "State and Federally Listed Endangered & Threatened Animals of California." CA Dept. of Fish and Game. (CDFG 2011)

While a host of factors contribute to the decline of threatened and endangered fish species in the Delta, one of the most significant is the operation of the CVP and SWP (CDFG 2010a, Obegi 2008). The Delta export pumps trap and kill fish, and upstream of the Delta, operation of reservoirs serving the projects decrease in-stream flows, alter the timing of flows, and decrease cold water – all critical to anadromous fish species' survival (Obegi 2008, SWRCB 2010).

Figure 26 demonstrates that particularly during dry periods (in gray) net Delta outflows (NDO), or the amount of freshwater moving into and through the Delta, are at their lowest. As noted by the Bay Institute (2010, p. 11-12): "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 chronic and severe 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."

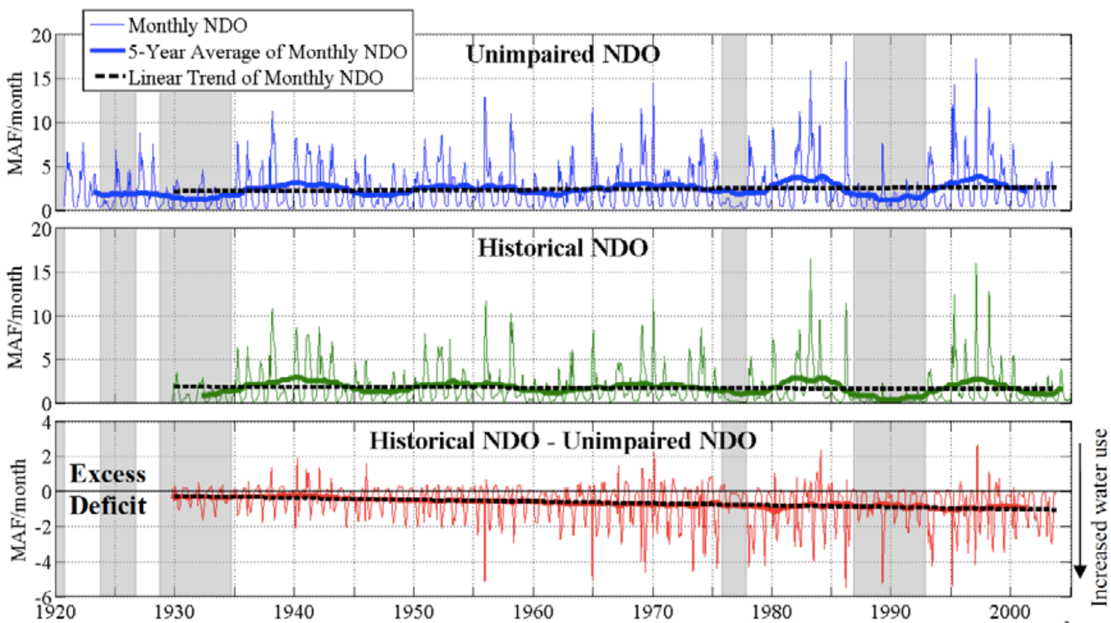


Figure 26. Monthly net Delta outflow under impaired conditions and actual, historical conditionsa
Source: CCWD 2010

Notes: Thin color lines indicate monthly net Delta outflow (NDO); thick color lines indicate the running five-year average of the monthly NDO; and the dashed black line indicates the linear long-term trend. The top panel is unimpaired (natural) NDO; the middle panel is historical, impaired NDO, which accounts for diversions, storage, and Delta exports; and the bottom panel is the difference between the historical and unimpaired NDO, where the cumulative effects of upstream and in-Delta diversions, reservoirs, and South–of-Delta exports result in decreasing overall net outflow.

Historically, reduced Delta flows correlate with fish population declines. Figure 27 demonstrates that the abundance of many Bay and Delta fish species is correlated with freshwater flow conditions in the Delta: the better the flow conditions, the more abundant the fish. The figure also shows the steep decline in fish abundance during the first year of the drought, with many populations reaching record lows.

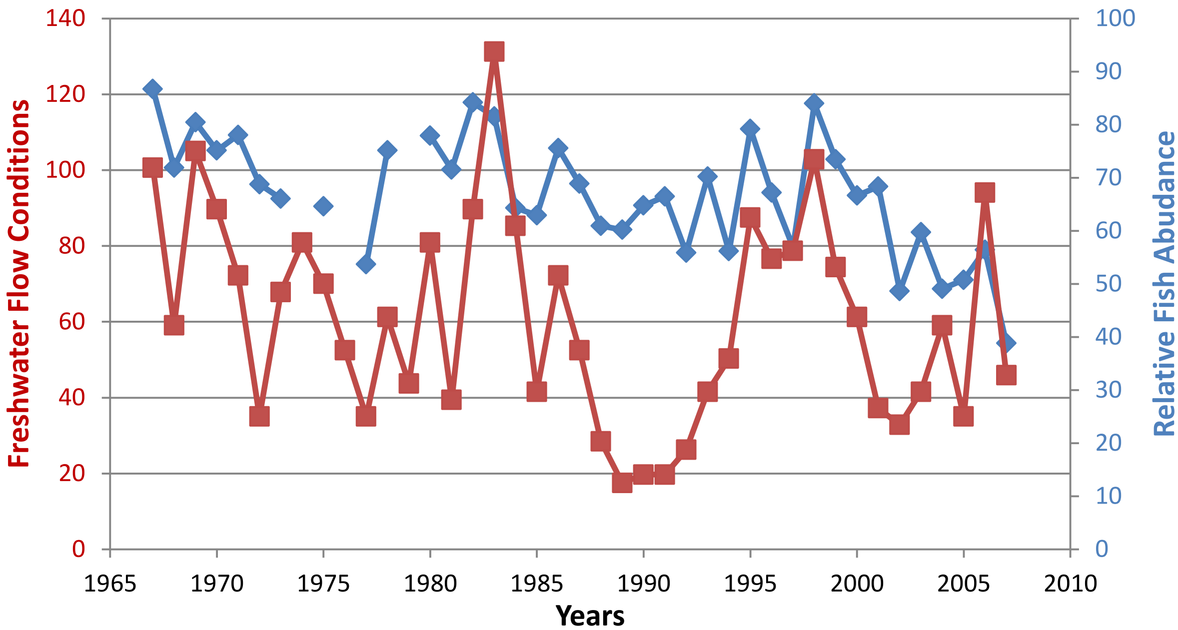


Figure 27. Freshwater flow conditions and relative fish abundance, 1967-2007
Source: Reproduced from data compiled in Rosenfield et al. 2010

Note: Flow conditions are the results of The Bay Institute's Freshwater Flow index, a composite of several quantitative indicators, including annual inflow as % of unimpaired; spring inflow as alteration in X2 location compared to unimpaired; peak flows (# days fewer of outflows>50,000 cfs (as 5-day running average); change in water year type; intra-annual variation (max-min X2 for the year); and actual spring inflow. Relative fish abundance is a composite measure of the relative abundance of the six species (delta smelt, longfin smelt, striped bass, splittail, American shad, and threadfin shad) for which the DFG Fall Midwater trawl abundance index is calculated. Relative abundance is calculated for each species as % of their average 1967-1991 average abundance (C. Swanson, personal communication).

While it is significant that all the cataloged Delta species saw record-low populations during the recent drought, it is also telling that are part of a longer-term declines: the FMWT index from 2000 onwards shows that the six species have experienced record lows 12 times in the past decade, and there has been a record-high only once during that same decade (for American shad in 2003, which is not an endangered fish) (see Figure 28). Confirming what many scientists have argued in years past, in 2010 the SWRCB found that according to the best available science, restoring the Delta's environmental variability "is fundamentally inconsistent with continuing to move large volumes of water through the Delta for export" (SWRCB 2010, pg. 6).

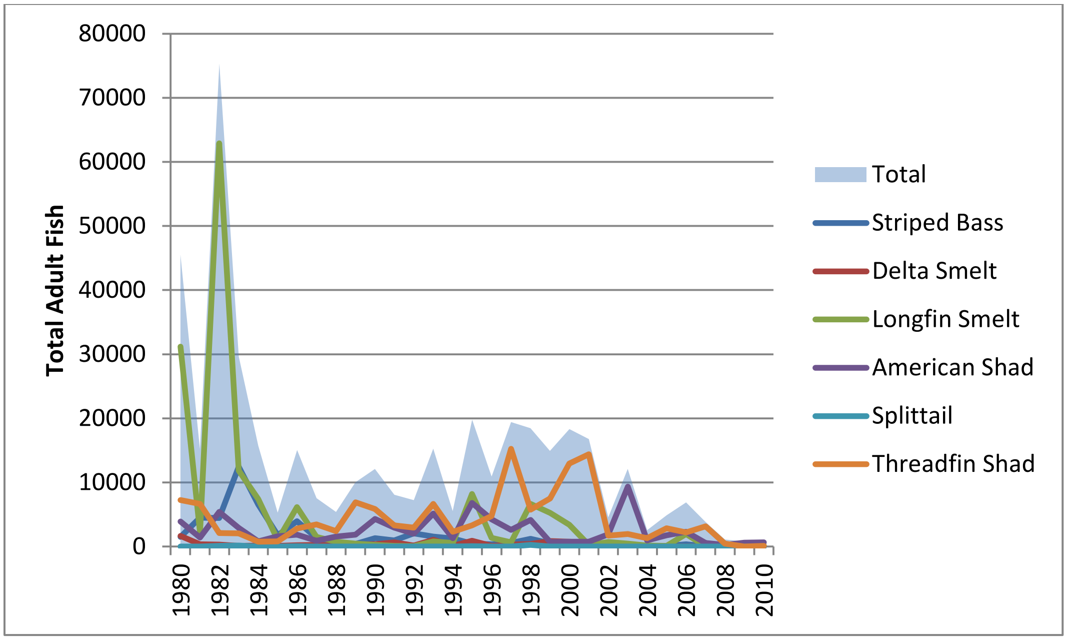


Figure 28. Indices for Delta fish species, 1980-2010
Source: Fall Midwater Trawl, Department of Fish and Game, 2010. (CDFG 2010a)

Note: Fall Midwater Trawl (FMWT) data is collected from the Delta estuary and Bay and upstream on both the San Joaquin and Sacramento Rivers and is used to calculate an annual abundance index of Delta estuary pelagic fish species. Fish populations fluctuate in size over time, yet certain species have experienced significant population declines over the past decade, and recent record lows can be seen in the 2007-2009 drought years. During the drought, Delta smelt, longfin smelt, American shad, and threadfin shad all were at record low levels; in 2010, striped bass and splittail were at record low levels as well (in two of the past three years, zero splittail were collected).

Whereas the 1987-1991 drought was more severe in terms of many of the other indicators we examined (e.g., decreases in runoff, agricultural production, and hydropower production), the 2007-2009 drought period resulted in the lowest historical numbers of many California fish species, exemplified by the closure of the commercial salmon fishery in 2008 and 2009. In response to the sudden collapse of Sacramento River fall Chinook salmon and the poor status of many west coast coho salmon populations, the Pacific Fishery Management Council (PFMC) adopted the most restrictive salmon fishery regulations in the history of the west coast of the U.S. The regulations included a complete closure of commercial and recreational Chinook salmon fisheries south of Cape Falcon, Oregon in both 2008 and 2009 (Lindley et al. 2009).

The number of fish that successfully complete the trip upstream to spawn, or spawning escapement, has been declining in the major California river systems over the past decade, with the greatest declines occurring during the drought years between 2007 and 2009. The major salmon runs in California occur within the Sacramento-San Joaquin River system. Figure 29 demonstrates that spawning escapement for Chinook salmon significantly declined during the drought years. In the wet water year prior to the drought (2006), Central Valley fall Chinook salmon spawning escapement totaled 194,975 adults. By 2009, escapement had declined markedly to only 24,731 returning adults.

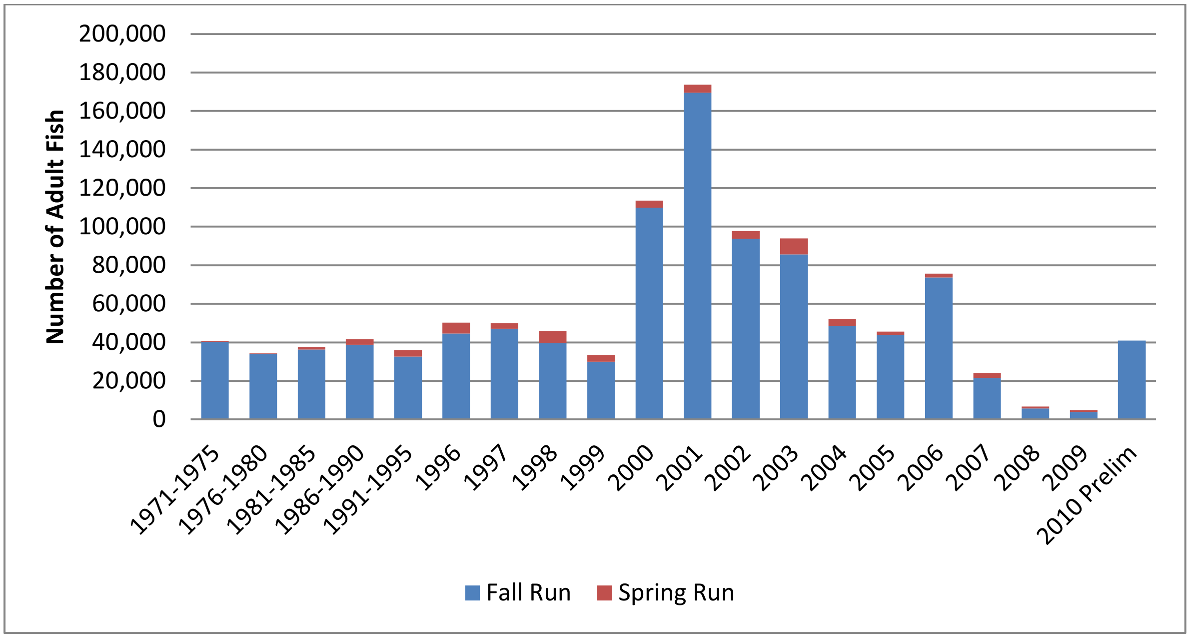


Figure 29. Spawning escapement for chinook salmon (numbers of adult fish) in the Sacramento and San Joaquin River systems

Source: PFMC annual review of ocean salmon fisheries, 2011. (PFMC 2011)

Salmon fared worse during this drought than in previous droughts; average spawning escapement from 2007-2009 (50,045 total fish) is 29% of the average escapement during the 1987-1991 drought (171,427 total fish). Reduced flows likely played a major role in this decline. Mesick et al. (2008) conducted an analysis of factors limiting the number of salmon and trout in the Tuolumne River, concluding that Chinook salmon recruitment (or the total number of adults in the spawning escapement and harvested in sport and commercial fisheries) is highly correlated with the production of smolt (young fish) outmigrants in the Tuolumne River, and that winter and spring flows are highly correlated with the number of smolts produced.[47]

[47] "Low spawner abundances (<500 fish) have occurred as a result of extended periods of drought when juvenile survival is reduced as a result of low winter and spring flows and not as a result of high rates of ocean harvest…Based on these results, the model for Chinook salmon focuses on winter and spring flows in the Tuolumne River as key factors controlling the production of adult Chinook salmon. The model for Central Valley steelhead also includes winter and spring flows in addition to summer flows and water temperatures as key controlling factors" (Mesick et al. 2008).

While poor ocean conditions were considered a proximate cause of decreased salmon stocks, the ongoing degradation of freshwater and estuarine habitats, decreased flows, and the subsequent heavy reliance on hatchery production were also identified as long-term contributors to the collapse of the stock (Mesick et al. 2008; Lindley et al. 2009). Today, nearly all of the state's returning adult salmon come from four hatcheries, as native populations have suffered due to poor flows and water quality (Taugher and Scott 2011). Hatchery salmon are genetically similar, and therefore more prone to disease and sudden population crashes (Taugher and Scott 2011).

Economic Impacts

The economic impacts of salinity changes and decreased environmental flows are very difficult to quantify as the valuation of ecosystem services is still in its nascent stages. Here we focus on the impact on fisheries and the related commercial fishing industry. The impacts of the drought on fisheries and aquatic resources are more obvious than terrestrial impacts, particularly for those species such as salmon in which survival shows a strong correlation to flow. The following information on salmon harvest and abundance is drawn from reports from the Pacific Fishery Management Council (PFMC) and from the California DFG.

In 2008 and 2009, the PFMC closed commercial salmon fishing and limited recreational fishing off the coast of California due to plummeting salmon stocks. Chinook salmon catch off the coast of California have been in decline for the past several decades. Between 1960 and 1980, commercial catch averaged 7.7 million pounds per year. Between 1980 and 2000, the catch averaged 5.2 million pounds per year. Catch average during the past decade (excluding years 2008 and 2009 when the fishery was closed, and 2010 limited season numbers) declined even further to 3.9 million pounds per year. In 1990, during the middle of last major drought, the salmon harvest was 4.4 million pounds. Yet, harvests during the most recent drought were much less: only 1.5 million pounds were landed during the first year of the drought (2007); no harvest during the closed fishery years of 2008 and 2009; and preliminary numbers document only 0.228 million pounds in 2010 (PFMC 2011) (see table 18).

Table 18. California's commercial salmon fisheries catch for troll chinook and coho

Year	Gross Revenue of Commercial Catch ($ million)	Commercial Pounds Landed (million)	Value per pound ($)	Commercial Vessels Landing Salmon
2000	12.875	4.337	2.97	852
2001	5.832	2.409	2.42	689
2002	9.350	5.008	1.87	708
2003	14.338	6.392	2.24	584
2004	20.483	6.230	3.29	741
2005	14.303	4.347	3.29	680
2006	5.739	1.043	5.50	477
2007	8.235	1.525	5.40	601
2008	(fishery closed)	-	-	-
2009	(fishery closed)	-	-	-
2010 (Prelim)	1.246	0.228	5.46	216

Source: PFMC annual review of ocean salmon fisheries, 2011. (PFMC 2011)

Note: Values are in inflation adjusted 2010 dollars.

In the second half of this decade, value per pound of commercial catch increased, demonstrating the effect of price changes. The inverse relationship between supply and price is much more pronounced in the fisheries sector than in the agricultural sector, where evidence of strong price responses to supply is only seen for individual crops at local levels, and not at the state level. While impacts to the salmon fishery from 2007-2009 must be observed within the context of longer-term decline in the health of the fishery, economic indicators demonstrate that salmon fishery gross revenues plummeted during the drought years. In comparison to the agriculture sector, which experienced record highs in gross revenue during the drought years, commercial salmon fishery gross revenues fell to record lows. As stated previously, we are not able to isolate the contribution of various causal factors to these changes in revenue.

Federal Disaster Payments

In 2008, the Secretary of Commerce determined a commercial fishery failure due to a fishery resources disaster for the ocean troll salmon fishery off the coasts on Washington, Oregon, and California. This determination allowed $170 million to be allocated to commercial and recreational members of the fishing communities affected by the salmon fishery failure[48] with 72% going to California, 15% to Oregon, and 13% to Washington (Pomeroy 2009). Although a fishery resource disaster was declared again in 2009, no new funds were allocated. Rather, the Secretary of Commerce wrote: "This disaster decision will ensure that the $53 million in unspent funds from 2008 will be available to affected fishing communities in Oregon and California" (U.S. Department of Commerce 2009).

The Pacific States Marine Fisheries Commission (PSMFC) administered the disaster relief program. Funds were available to fishermen, buyers, fishing guides and businesses dependent on fishing, with the amount awarded based on their role in and income associated with the fishery and other criteria, and limited to no more than $250,000 (Pomeroy 2009). Funds for commercial fishermen and buyers were based on the pounds of salmon they landed or received in a recent best year, multiplied by a price per pound. Fishery-support businesses that could document that at least 30% of their business is salmon fishery-related could be awarded 50% of their salmon-related losses initially (Pomeroy 2009). Thus, unlike crop insurance, which only covers particular crops and farms that have taken out insurance policies, this disaster assistance is need-based and dispersed among a broader array of affected individuals and industries.

Employment and Port-Related Income

The gross revenue of the commercial salmon catch in California was $49 million in 1979; the average revenue between 1980 and 1990 was roughly $30 million, and between 1990 and 2000 it was $10.5 million (all in 2010 dollars). Between 2000 and 2006, the average annual revenue was approximately $12 million. In 2007, the first year of the drought, gross revenues were $8 million, followed by the closure of the fishery for 2008 and 2009. In 2010, a limited season yielded the low preliminary annual catch value of $1.2 million.

The average gross revenue during the drought years was $3 million (primarily due to the closure of the fishery in 2008 and 2009). Therefore, the drought period average gross revenue is a 90% decline from 1980-1990 average values and a 75% decline from 2000-2006 average values. The Eberhardt School of Business estimates that salmon fishery closures during the drought resulted in a loss of approximately 1,800 jobs and $118.4 million in income compared to the salmon fishery in 2004 and 2005 (Michael 2010).

Salmon industry trends demonstrate the gradual decline of California fisheries and related port economies. Declines in the issuance of commercial and sport fishing licenses and permits for all fisheries (not just salmon) during the drought period appear to be part of a longer-term trend (see

[48] This determination was made under Section 312(a) of the Magnuson-Stevens Fishery Conservation and Management Act (see Public Law 110–246).

Figure 30). Nevertheless, notable declines did occur during drought years for the fishery as a whole. The DFG issued 30% fewer commercial fishing licenses during the final two years of the drought (2008, 2009) than it did in 2000, and issued 10% fewer sport fishing licenses over the same time period as compared to 2000.

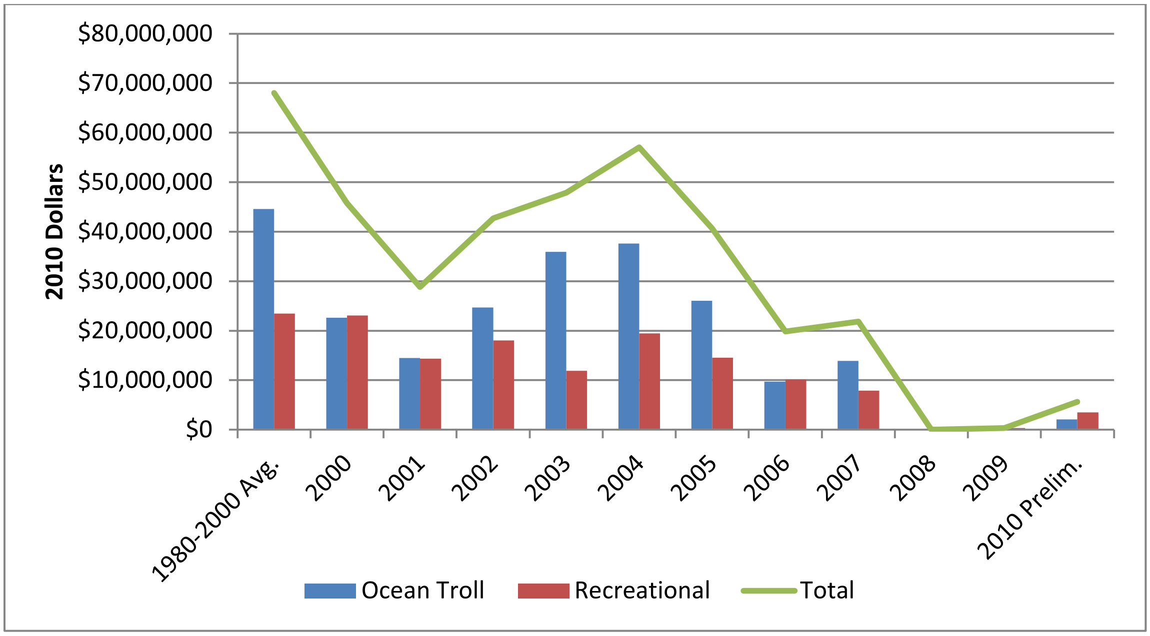


Figure 30. State personal income impacts in California coastal communities of the commercial and recreational ocean salmon fishery
Source: PFMC 2011

Overall, many fisheries have decreased steadily over the past decade and drought period trends appear to be part of a larger trend in the decline of the industry. This in some ways parallels the long-term decline in agricultural acreage and numbers of farms, however the comparison differs in terms of production and revenue generated – while the agricultural sector has thrived in terms of continued, and in some cases, even increased yield and revenue, fishery catch and revenues have collapsed.

Impacts to Energy

California is fortunate to have extensive hydroelectric power capacity. Hydroelectricity is relatively inexpensive compared to almost every other form of electricity generation, it produces few or no greenhouse gas emissions, and it is extremely valuable for load-following and satisfying peak electricity demands, which are often the most difficult and costly forms of demand to satisfy. The amount of hydroelectricity that can be generated in any given year, however, is directly related to runoff and the amount of water stored in California's reservoirs.

During droughts, total hydropower production drops in close relationship to the amount of water flowing in California's major rivers. Figure 31 shows total hydroelectricity generation in

California from 1983 to 2009, plotted together with the unimpaired natural water flows in the Sacramento and San Joaquin Rivers over the same period. The correlation between the two curves is strong: when runoff falls, hydroelectricity production falls, and when runoff is high, hydroelectricity production increases.

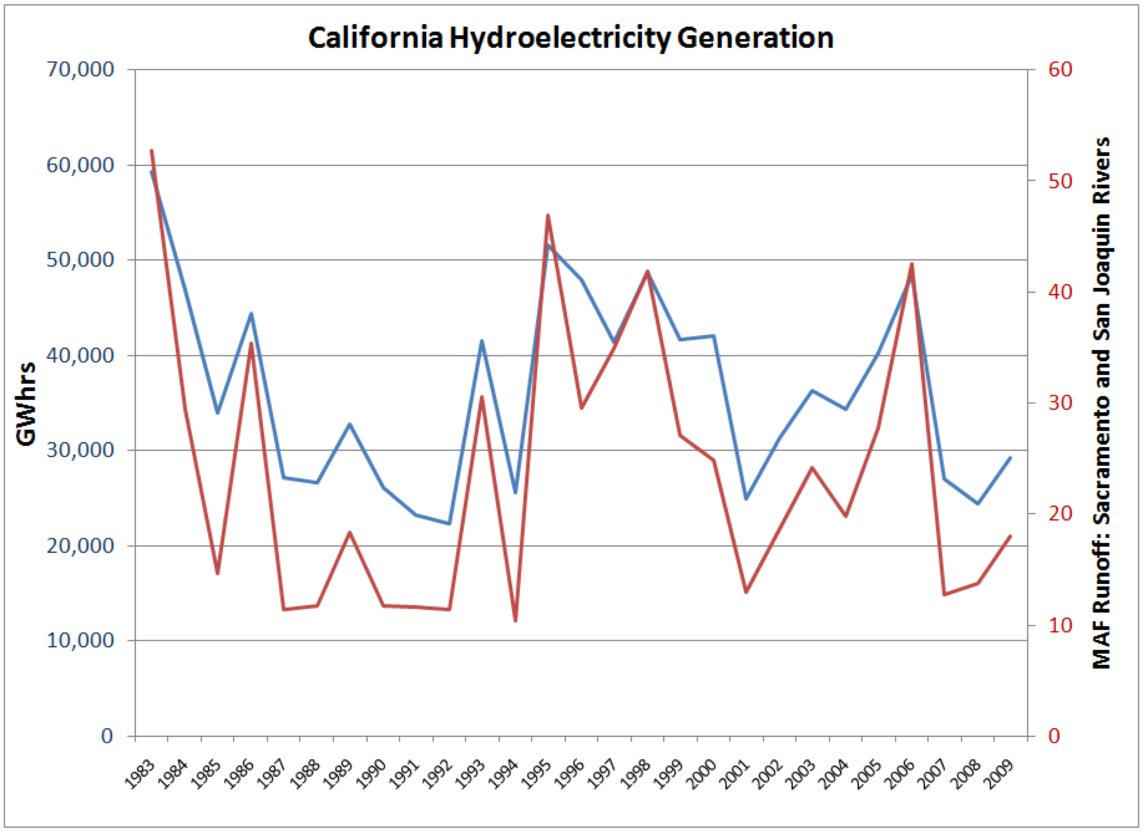


Figure 31: California hydroelectricity generation from 1983 to 2009 together with unimpaired runoff from the Sacramento and San Joaquin Rivers, showing the strong relationship between river flow and hydro generation.
Source: Data on hydroelectricity production from the California Energy Commission; data for runoff from the Department of Water Resources. (CEC 2011, DWR CDEC 2011)

In an average year in California, around 15% of the state's electricity (excluding imported power from outside the state) is generated from hydropower facilities. The total fraction of the state's electricity produced by hydropower has been falling over the past quarter century as demand for electricity has continued to grow but installed hydroelectricity capacity has remained relatively constant (see Figure 32, which shows the percent of total California electricity generation produced by hydro plants). The ability to expand California's hydroelectric capacity is limited. Few undammed rivers, little unallocated water, and growing environmental constraints have all contributed to the difficulty of adding new hydropower capacity.

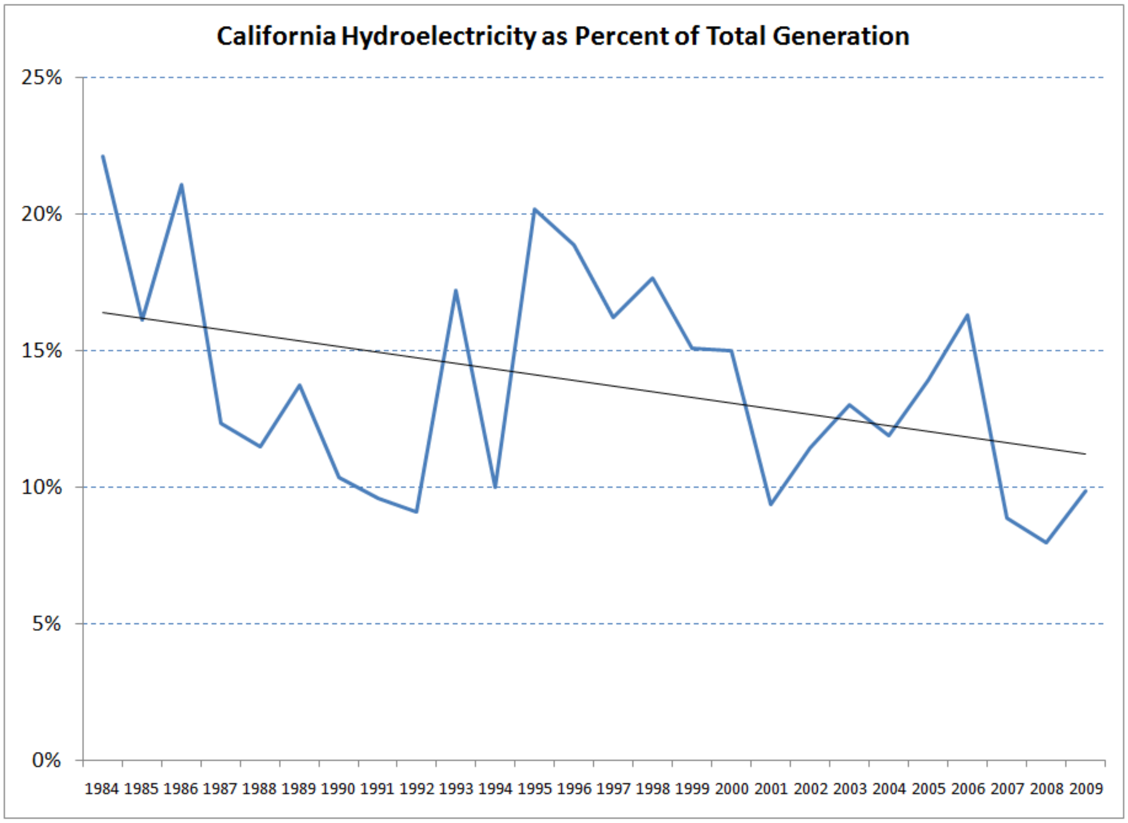


Figure 32: California hydroelectricity as a percent of total State electricity generation. The fraction of electricity provided by hydro systems has been falling from between 15 and 20 percent to around 10 percent in the past quarter century as overall electricity production has grown.
Source: Data from the California Energy Commission. (CEC 2011)

Figure 33 shows total electricity produced for California from 1997 to 2009 by major generating source. During dry years, hydroelectricity production as a fraction of total state electricity demand can fall to well under 10%. The difference is typically made up by electricity from natural gas facilities. Figure 33 demonstrates that the growth in overall electricity production has been dominated by increases in natural gas generation. Hydroelectricity has fluctuated over the years in relation to hydrologic conditions, coal generation has been declining, and renewable and other in-state production has been increasing, but at a slower rate than natural gas production.

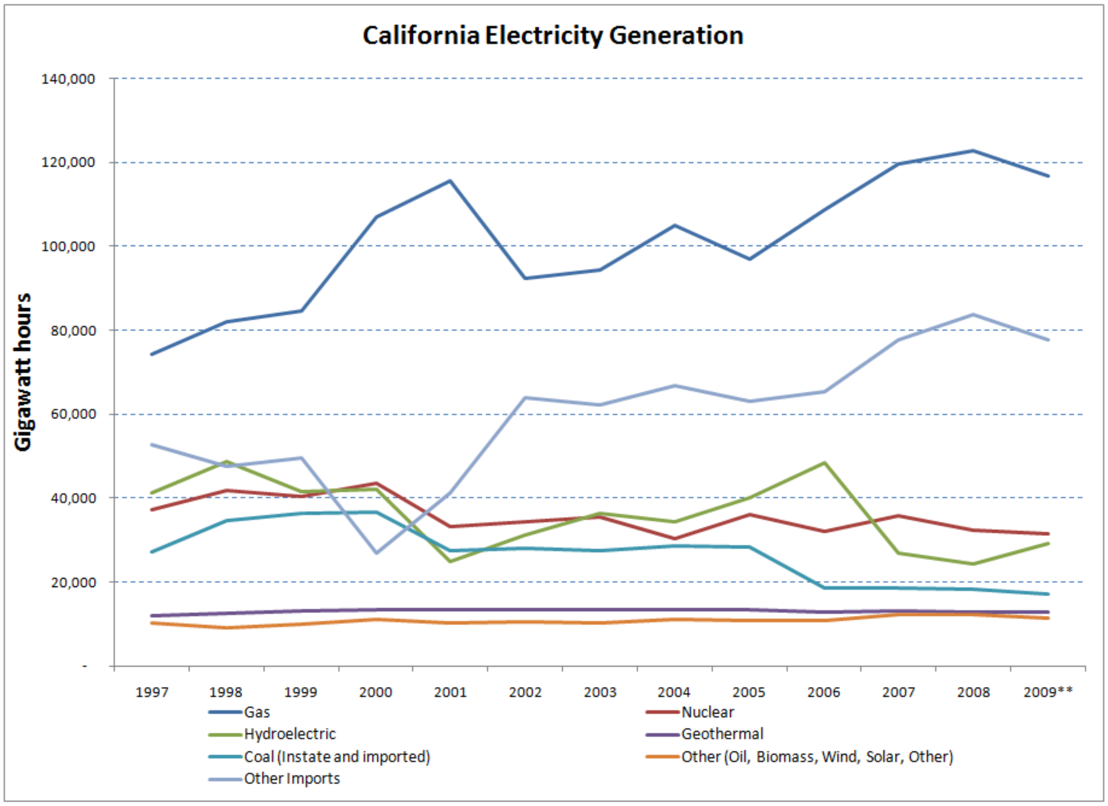


Figure 33: California electricity production by generating source from 1997 to 2009.
Source: Data from the California Energy Commission. (CEC 2011)

During the recent drought in California in the years 2007, 2008, and 2009, hydroelectricity production accounted for only 9%, 8%, and 10% of the state's overall electricity generation, respectively (see Figure 32). This lost hydropower was made up primarily by burning more natural gas and by increasing purchases from out-of-state sources. Because the cost of generating electricity with natural gas is substantially higher than the cost of producing hydropower, the drought led to a direct increase in electricity costs borne by California ratepayers.

One additional factor that contributed to the impacts of the drought on California's energy system was the constrained transmission capacity and connections with neighboring regions. Increased construction of transmission lines could have permitted the Pacific Northwest, for example, to increase delivery of lower-cost or renewable power during parts of the drought. This may have reduced the need of California to burn costly and more polluting natural gas.

Economic Impacts and Environmental Costs

Using estimates from the California Energy Commission of the amount of hydroelectricity generated in an average year compared to that generated during the 2007-2009 drought, it is possible to calculate the extra natural gas burned. During the three-year drought period, approximately 30,000 gigawatt hours (GWhrs) of lost hydropower were made up with additional natural gas generation. Using the average levelized cost of California's in-service combined cycle gas turbines (around 11.5 cents per kWhr) compared to the levelized cost of hydroelectric facilities (around 6 cents per kWhr) gives an estimate of the added cost to California ratepayers of around $1.7 billion.

In addition to these direct economic costs, there are environmental costs associated with the additional combustion of natural gas, including increased air pollution in the form of nitrous oxides (NO_x), volatile organic compounds (VOCs), sulfur oxides (SO_x), particulates (PM), carbon monoxide (CO), and carbon dioxide (CO_2) – the principal greenhouse gas responsible for climatic change. Using the standard emissions factors from the California Air Resources Board and the California Energy Commission (see Table 19) for conventional combined cycle natural gas systems, the drought led to the emissions of substantial quantities of additional pollutants (see Table 20). In particular, nearly 13 million tons of additional carbon dioxide, or about a 10% of increase in average annual CO_2 emissions from California power plants, along with substantial quantities of nitrous oxides, volatile organic chemicals, and particulates. The 0.070 lbs per MWhr of NOx and 0.208 lbs per MWHR VOC represent approximately a 10% annual increase of these pollutants into local air/watersheds and are known contributors to the formation of smog and triggers for asthma.

Table 19. Criteria Pollutant Emissions Factors (pounds per MWhr) for Conventional Combined Cycle Natural Gas Generation

NO_x	VOC	CO	SO_x	PM10	CO_2
0.070	0.208	0.024	0.005	0.037	815

Note: Average values given.

Table 20. Total Additional Emissions from Natural Gas Use During Drought 2007-2009 (tons)

NO_x	VOC	CO	SO_x	PM10	CO_2
1,110	3,300	380	80	590	12,900,000

Source: CATEF - California Air Toxics Emission Factor Database, 2011. (ARB 2011)

Note: NO_x stands for nitrous oxides, VOC for volatile organic compounds, CO for carbon monoxide, SO_x for sulfur oxides, PM10 for particulate matter (with a diameter of 10 micrometers), and CO_2 for carbon dioxide. All are greenhouse gases (GHGs) responsible for climate change.

These estimates are conservative, assuming that all additional natural gas combustion came from more environmentally-friendly combined cycle systems. The economic costs of conventional or advanced simple cycle natural gas systems are 3 to 7 times higher than the cost of combined cycles, and emissions are also higher due to lower efficiencies of combustion. Thus, some of the drought's most direct and costly impacts were to air quality and California electricity ratepayers.

Conclusions

This report provides the most comprehensive and updated information on the impacts of the 2007-2009 drought on California's economy and environment, and offers insights into what the recent drought tells us about California's vulnerability to the possibility of more frequent and severe droughts in the future. Droughts are a hallmark of the California climate, and it is increasingly important to have sustainable strategies to cope with growing pressures on the state's water resources, including population growth, ecosystem decline, and climate change. The 2007-2009 drought in California serves as a multi-year case study through which we may observe impacts, vulnerabilities, and adaptations across human and environmental groups, and across state and regional economic sectors. This report details the highly varied vulnerabilities of the agricultural, energy, and environmental sectors to the drought.

The most complex and public impacts of the drought occurred in California's agricultural sector. Because the state's hydrology is highly variable and due to the state's sophisticated and extensive water infrastructure, certain water users experienced few adverse impacts while others experienced much greater effects – even within the same region. For instance, during 2009, agricultural water users with priority contracts south of the Sacramento-San Joaquin Delta (e.g., settlement and exchange contractors) received 100% of their allocation, while some other contract holders saw their water supply severely curtailed, down to as low as 10% in 2009. Even in second year of the most severe drought on record (1976-1977), settlement and exchange contractors received 75% of their allocation, showing how legal and institutional factors play a role in buffering some users from droughts.

Many in the agricultural community have developed complex coping strategies to buffer themselves from drought impacts, such as shifting away from water-intensive and/or lower value crops and participating in short-term water transfers. While these strategies have some limitations, they can be sustainable in the long-term. However, a chief coping strategy widely employed by the agricultural sector during the drought was greatly increased and unsustainable groundwater pumping in the Central Valley. Many groundwater basins are already overdrafted, especially in the Tulare Basin in the San Joaquin Valley. The recent drought led to dramatic additional declines in groundwater levels and volumes in the San Joaquin Valley's groundwater aquifers between 2007 and 2009. Unless groundwater levels are intentionally recharged in wet years, this short-term approach is unsustainable and will not work for longer or more severe droughts. In addition, climate change projections indicate many parts of the state will experience reduced water supplies in the future due to warmer temperatures, decreased snowpack, and increased evaporation (Knowles et al. 2006) and current coping strategies must be evaluated in the context of these changed conditions.

The report also addresses drought impacts to ecosystem health by describing trends in several environmental indicators, including increased salinity in the Delta, decreased freshwater environmental flows in California rivers and streams, and collapsing freshwater and ocean fisheries. The degraded condition of many of the state's aquatic ecosystems, particularly in the Delta, has led to acute vulnerability as demonstrated by fish populations that are highly sensitive to change. For instance, the closure of the salmon fishery in 2008 and 2009 was linked to poor ocean conditions. Yet, long-term declines in suitable fish habitat, water quality, and water quantity (flows) – during both drought and non-drought years – all contributed to the collapse of native salmon stocks, as did their replacement with hatchery-reared salmon (which are genetically less diverse and more vulnerable to disease and die-off than native salmon stocks). Populations of native Delta fish species, including the endangered Delta and longfin smelt, fell to record low levels during the drought years. The abundance of these populations serves as an important indicator of overall aquatic ecosystem health in the Delta estuary and its tributaries.

The drought also led to decreases in stream flows below levels necessary to maintain conditions for species survival and reproduction (see unmet flow objectives, Table17), further exacerbating impacts to aquatic species. Not all populations were affected equally. Some remnant native populations of salmon (including late-fall, winter and spring Chinook salmon) seem less affected by variability in natural conditions (Lindley et al. 2009). This suggests that life-history diversity can buffer these fish species from the impacts of environmental variation, such as changes to water flow or temperature caused by drought conditions. "The situation is analogous to managing a financial portfolio: a well-diversified portfolio will be buffeted less by fluctuating market conditions than one concentrated on just a few stocks" (Lindley et al. 2009). Given the precipitous declines in native fish species over the last decade and during the drought, it is wise to consider scientific analyses of how to restore critical flows to California's aquatic ecosystems and reduce vulnerability to short-term adverse oceanic or hydrologic conditions (SWRCB 2010), particularly since species collapse often triggers other environmental consequences as well as a series of legal protections that can be onerous and expensive.

Other sectors of the California economy are also affected by drought, especially the state's energy system. A substantial fraction of electricity production in California comes from hydroelectric plants, and hydropower production is extremely vulnerable to changes in precipitation and runoff. During the recent drought, hydropower production was cut almost in half. This lost hydropower was made up primarily by burning more natural gas and by increasing purchases from out-of-state sources. These sources were more economically and environmentally costly. California electric customers paid approximately $1.7 billion more for replacement energy, and the combustion of natural gas contributed an additional 13 million tons of carbon dioxide along with other pollutants to the atmosphere.

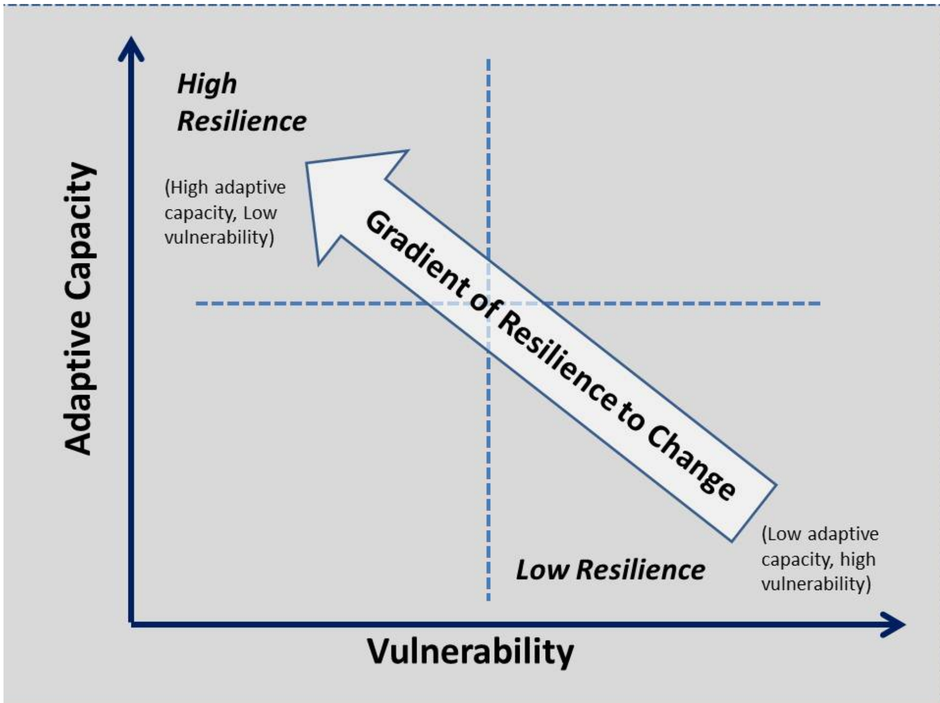
Preparing for the Next Drought

Based on the lessons from the 2007-2009 drought, we provide a series of recommendations below to reduce California's vulnerability to the next, inevitable drought. Because drought is a pervasive problem that is impossible to prevent, managing drought and drought risk are essential. Historically, drought management has been based on crisis management, a reactionary approach that involves providing relief to those affected by drought (Cooley et al. 2008). Some contend that this approach can promote dependency, encourage poor management practices, and may serve to increase long-term vulnerability: "Unfortunately, the response efforts of many nations have had little, if any, effect on reducing vulnerability, largely because of their emphasis on emergency assistance. In fact, vulnerability to drought has increased in some settings because of relief recipients' expectations for assistance from government or donors… Disincentives to proper management of the natural resource base characterize the provision of relief in most countries" (Wilhite 1996). For example, farmers may plant high water-use crops with greater commercial value rather than drought-tolerant crops with lesser commercial value because government relief would provide income in case of crop failure (Cooley et al. 2008).

In recent years, the global community has begun to transition away from crisis management in favor of applying risk management and resilience frameworks. Risk management efforts seek to identify risks associated with a particular type of event, such as drought, understand the underlying cause of those risks, and develop appropriate mitigation strategies to avoid or limit the impacts associated with those risks (Cooley et al. 2008). Resilience frameworks help those analyzing a risk to examine the speed of recovery from a disturbance (Pimm 1984, Tilman and Downing 1994), and to determine the magnitude of a disturbance (relative to a threshold) that can be absorbed before a system changes its structure or the processes and variables that control its behavior (Holling 1995, Gunderson and Holling 2002). Figure 34 below diagrams the relationship between vulnerability, adaptive capacity, and resilience. Greater resilience can be developed by reducing vulnerability and/or increasing adaptive capacity.

For California to becoming more resilient to future droughts, it is imperative that the state improve drought planning and risk management efforts, which include the following: developing monitoring systems that provide early warning and inform planning processes to prepare for drought; impact and vulnerability assessments to determine at-risk regions and populations; and appropriate mitigation and response measures to reduce vulnerability and increase adaptive capacity (Wilhite 2000). Examples of critical steps to enhance California's resilience to the next drought are described further below.

Figure 34. The relationship between vulnerability, adaptive capacity, and resilience.



Source: Pacific Institute 2011

Monitoring and Planning

Because of the complexity and lack of understanding about the driving forces that result in drought, accurately predicting droughts is impossible. Monitoring and early warning, however, provide the public and policymakers with information essential for detecting possible or oncoming drought conditions. In addition, planning programs are integral to determining which potential mitigation and response actions are the most appropriate for particular sectors and particular regions. For example, an early-warning system can notify farmers about projected drought conditions and aquifer levels, while planning processes can help inform what types of crops are grown, when they are planted and harvested, and how they are fertilized (Cooley et al. 2008).

To support this effort, the appropriate institutional capacity must be in place to collect and assess the data and inform the public. Thus, state or local institutions should collect and maintain data on a range of meteorological and hydrological conditions essential to qualifying drought and drought response, including surface and groundwater extraction and levels, reservoir levels, soil moisture, snowpack, precipitation, temperature, and humidity (Wilhite 1997). While California tracks some of these conditions, major pieces of data (e.g., surface and groundwater extraction) are lacking. In addition, the state provides little real-time information to the public and few comprehensive, accessible, and electronically-available databases.

Future work on such efforts may enable us to detect changes earlier, with greater accuracy, and at greater spatial resolution, allowing informed response and planning on the part of agricultural, energy sector, and environmental management communities. Recent technological advances are available to support this effort. For example, satellites can monitor vegetation health, moisture and thermal conditions, and fire risk potential over wide areas. In a recent discussion of remote sensing and early drought warning, Kogan (2000) voices optimism about technological breakthroughs: "…we begin the 21st century with exciting prospects for the application of operational meteorological satellites in agriculture…drought can be detected 4-6 weeks earlier than before in any corner of the globe and delineated more accurately, and its impact on grain production can be diagnosed long before harvest. This is the most vital step for global food security and trade."

Impact and Vulnerability Assessment

A drought impact assessment identifies those regions, activities, and populations that are most affected by drought. While an impact assessment identifies the effects of drought, the vulnerability assessment attempts to determine the underlying cause of drought-related impacts. Together, these assessments enable the development and implementation of informed and targeted response and mitigation plans (discussed below). According to Knutson et al. (1998), "[d]rought may only be one factor along with other adverse social, economic, and environmental conditions that creates vulnerability." A vulnerability assessment attempts to identify the root cause of human, environmental, or economic vulnerability so that mitigation strategies can be devised to address those vulnerabilities (Wilhite et al. 2005). This approach changes the nature of the discussion and lies at the heart of risk management.

For an agency or group to conducting an impact and vulnerability assessment, they must include representatives from all impacted sectors as well as local community members. This bottom-up approach can be an important component of capacity building by empowering individuals to identify potential risks and possible mitigation strategies most suited to local circumstances. A participatory approach like this creates a sense of ownership over the solutions and increases the likelihood of implementation of appropriate response efforts, and the success of those efforts. For instance, it is critical to work with the agricultural community to develop more resilient coping strategies to reduce the vulnerability of the agricultural sector in the future, but also to make sure that all parts of the sector are included, not just the most economically or politically powerful. Such assessments must also include the best science related to future climate change, not just current climatic conditions. A recent California Climate and Agriculture Network assessment states: "California has made considerable progress towards understanding how climate change may impact the state's agriculture sector. But too few research studies have been conducted on how agriculture might *respond effectively* to…adapt to a changing climate" (CalCAN 2011, emphasis added). We urge better funding for critical agricultural technical assistance and extension programs, and studies that develop comprehensive mitigation and adaptation strategies with the agricultural community, especially with regard to water supply vulnerabilities

In addition, systems with particularly high vulnerability and low adaptive capacity should be identified and steps should be taken to increase their resilience (see Figure 34). For instance, recently the State Water Resources Control Board (SWRCB) developed flow criteria to preserve the attributes of the Sacramento-San Joaquin Delta's naturally variable system to which native fish species are adapted.[49] Scientists argue that restoring some level of functionality to the Delta's ecosystems, in particular, is critical to avoid continued collapse of fisheries, leading to increased endangered species listings and decreased flexibility of water project operations. The SWRCB flow criteria is an example of a scientific assessment resulting in a plan of proposed action that would, according the best available science, increase the resilience of endangered species so that they might have the capacity to recover from multiple stressors – such as future droughts.

Mitigation and Response

Mitigation and response are core elements of drought management, especially when efforts are made in advance to reduce vulnerabilities. ***Mitigation*** refers to actions and programs taken before and in the early stages of a drought to reduce drought-related risks; whereas ***response*** refers to actions taken immediately before, during, and directly after drought to reduce drought impacts (Knutson et al. 1998). Mitigation is anticipatory and focuses on risk reduction, whereas response is reactive and focuses on impact reduction. While response can be critical to relieve suffering and prevent deaths, solely relying on responses can create dependency by encouraging unsustainable practices, and may miss efforts that are likely to be especially cost-effective (Cooley et al. 2008). As noted by Abramovitz (2001) "A dollar spent on disaster preparedness can prevent $7 in disaster-related economic losses." Additionally, response alone may result in greater future harms, such as the potential for groundwater aquifer depletion in the case of an extended drought (see Groundwater section).

Table 21 highlights mitigation and response strategies for some of the sectors affected by drought. As this table suggests, a number of mitigation strategies are available within different sectors, and mitigation strategies in one sector can have a positive effect on other sectors. For example, improvements in the efficiency of water use in the agricultural sector can minimize that sector's reliance on the existing supply and reduce unnecessary water use, thereby maximizing the current supply and reducing the drought's impact on the other sectors, such as the environment. Likewise, planting drought-resistant crops reduces agricultural losses, with benefits for the economy such as increased farm revenue and decreased pay-outs in the form of federally-subsidized crop insurance.

[49] "These criteria include: 75% of unimpaired Delta outflow from January through June; 75% of unimpaired Sacramento River inflow from November through June; and 60% of unimpaired San Joaquin River inflow from February through June" (SWRCB 2010).

Table 21. Mitigation and Response Strategies for Drought-affected Sectors.

Impact Sector	Mitigation Strategy	Response Strategy
Water Supply and Quality	Water conservation and efficiency programs Groundwater recharge Rainwater capture Increased water recycling New surface storage New/deeper wells Better regional infrastructure Financing of water and wastewater treatment Establish longer-term water transfer programs/arrangements and systems for monitoring and evaluation of transfers	Impose short-term water-use restrictions. Truck-in additional supplies Undocumented, short-term water transfers
Fish and Wildlife	Restore critical ecosystem flows Protect/restore critical habitat Alter fishing/hunting limits Fishery and wildlife agencies act on the objectives of long-term ecosystem protection goals and objectives	Expand production at fish hatcheries Impose temporary bans on recreational or commercial fishing and hunting. Fisheries and wildlife agencies respond to emergency-driven modifications to management plants Lawsuits filed for temporary emergency protections of endangered species
Agriculture	Plant drought-resistant crops Adjust grazing schedule and intensity Improve soil moisture management Implement conjunctive management Provide better/affordable access to efficient irrigation technologies and products	Use insurance, grants, and loans to reduce economic impacts. Expand short-term groundwater mining. Fallow land or alter cropping patterns on an annual basis
Energy	Expand energy conservation and efficiency programs Diversify the state's energy portfolio with a focus on renewable energy sources Expand transmission capacity with neighboring states, particularly those with renewable energy sources	Purchase natural gas to replace hydropower Implement energy short-term demand-reductions programs Raise energy rates to encourage conservation

Source: Knutson et al. 1998; Mosley 2001; Najarian 2000; National Drought Mitigation Center 2005; Wilhite 1993.

Although California's agricultural productivity remained high during the drought, some of the adaptation strategies were short-term responses that would not provide water security in the face of a longer or more severe drought. As discussed earlier, many agricultural regions adapted to reduced surface water supplies by mining groundwater. Negative impacts of groundwater mining include localized land subsidence, increased well drilling costs, and increased pumping costs. While groundwater mining is an unsustainable response strategy, conjunctive management of surface and groundwater resources (see Sidebar 3) has the potential to be a long-term mitigation measure that can reduce vulnerability to future supply shortages. Some water districts in California employ conjunctive management, but for this strategy to increase California's agricultural sector resilience, conjunctive water use would need to be more widely and comprehensively implemented and monitored.

In conclusion, although it's impossible to predict when the next drought will occur in California or how long it will endure, we do know that another drought is inevitable. While some drought-prone countries have reformed their drought monitoring, planning, and response strategies (e.g., Australia), the U.S., and California, in particular, has yet to do so. In order for California's agricultural sector, economy, and environment to become more resilient to future droughts, it will be critical to shift from crisis-driven responses to development and enactment of long-term mitigation measures. All of the sectors that we examine in this report (agriculture, energy, and the environment) are currently vulnerable to longer or more severe droughts and should develop more comprehensive drought planning and mitigation measures to reduce the potential for human, environmental, and economic harm.

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