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The 2014 drought and water management policy impacts on California's Central Valley food production

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Abstract Water is a scarce resource in the West, creating intense competition among user groups. The problem is compounded by climate change. During 2014 and 2015, California experienced one of the worst droughts in 160 years of record keeping. The US Bureau of Reclamation announced zero water allocation for Central Valley Project agricultural water service contractors—with a devastating impact on food producers. Many farmers have fallowed their fields because there was not enough water to meet their needs, and thousands of acres of citrus, almond, and other perennial crops have been ripped out. The reduction in irrigation water supply has forced farmers to draw on underground water, which is expensive and unsustainable. Water managers have to decide between supplying water for cities, agriculture, and environmental services (e.g., water flow through the San Francisco Bay-Delta). Farmers perceive the collapse of their water allocation as, in part, a "regulatory drought" brought on by political decisions about who should have the water. The growing demands of other sectors have been met at the expense of agriculture. Uncertainties in the current political process not only undermine the reliability of the agricultural water supply but also diminish the industry's ability to make long-term adaptive decisions. The implementation of environmental laws and policies has been particularly distressing to farmers because of the large quantity of water designated for environmental use and the apparent weakness of scientific evidence to justify it. The realization of supposed benefits, such as restoration of endangered fish populations, has not been convincing. Moreover, information is lacking on alternative management options that might be more effective. Two recommendations are presented as a means to increase the resilience and reliability of the water supply for all user groups: (1) a mediated settlement generated by all stakeholders involved in water use sectors that bear upon the comprehensive and long-term management of the San Francisco Bay-Delta and threatened and endangered species that depend upon it and (2) an increase in water storage infrastructure to buffer future fluctuations in snowpack runoff.

Keywords California · Drought · Water · Policy · Regulations

Introduction

California is currently experiencing a record-breaking drought with drastic consequences, including an unprecedented reduction in water for agricultural use. The drought experienced by agricultural producers is, in part, an artificial drought created by regulations that reduce water deliveries to farms as a strategy for the recovery of populations of protected species in the rivers and San Francisco Bay-Delta system. Water use in the American West has always been an issue surrounded by competition and contention, which is exacerbated during times of drought creating frustration, uncertainty, and fear among the various user groups. A feeling of competition is particularly intense between agricultural water users and proponents of instream use for ecological services and protected fish populations.

With the record dry conditions experienced over the previous years, coupled with water supply reductions related to regulatory actions, water allocations for all use sectors were

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reduced with some agricultural water users receiving no allocations at all from the Central Valley Project (CVP). Table 1 shows the allocations for the CVP, a federal water project that spans the length of California, for 2014 and the initial allocations for 2015. Settlement contractors, primarily agricultural water users, have water rights that predate the federal project, making them priority rights on the system, yet even allocations to those senior water rights holders are being reduced. Resilience in food systems is inherently dependent on the water resources available to producers. This article approaches the issue of food resilience by looking at vulnerabilities in the water management system that delivers water to California farmers, specifically identifying the health of the San Francisco Bay-Delta ecosystem as it pertains to those water deliveries.

While reduced snowpack is certainly contributing to the water crisis in California, the application of environmental laws and policies has undermined one of the primary uses of the CVP, supplying water for agriculture, with little apparent benefit to the environment. A large portion of the water in the Sacramento and San Joaquin rivers is left in stream to flow to the ocean to provide specific conditions in the rivers for salmon and sturgeon, species protected by state and federal policies. The San Joaquin Valley farms and communities use fresh water pumped from the San Francisco Bay-Delta to supplement their needs; however, over the past several decades, exports via those delta pumps have been reduced as a means to comply with water quality standards in the Bay-Delta and to address the decline in the delta smelt population, another protected species. This article focuses on these pump exports from the Delta as key indicators of policy decisions throughout the state regarding agricultural water allocations and fisheries management. Presently, agriculture in California does not have a reliable supply of water, which undermines the industry's ability to make long-term decisions regarding adaptation and resiliency.

The frustrating fact to agricultural producers is that the water cutbacks that have already occurred are not increasing the populations of salmon and the delta smelt, the species listed for protection under the federal Endangered Species Act (ESA). Recommendations discussed in this article aim to maximize the benefits of all water uses including agriculture and ecological services. The National Research Council (2012) has suggested that reducing pumping for agricultural water does not significantly impact fish populations; whereas, other stressors along the systems, such as wastewater contaminants and nonnative aquatic species, do have a more significant impact on the health of the ecosystem and the populations it supports. Protected fish populations could be more effectively managed by focusing on other stressors to the Bay-Delta system while also providing a reliable water supply for agricultural use.

It is important to note that the lead author, as the Executive Director of the Family Farm Alliance, advocates for Western farmers and ranchers; however, this paper does support its arguments with logic, evidence, and citations and provides a perspective that is underrepresented in scholarly literature. Although, much of the information provided in this paper comes from the author's personal involvement in Western water policy issues—including extensive engagement with state and federal agencies, the judicial system, and Congress—published reports are referenced wherever possible.

This article begins by describing the significance of California agriculture and the water supply and distribution system it depends on. It then explains the competing demands for water between agriculture and protected fish populations. The competition between these two water use sectors is illustrated through the regulatory focus on water exported from the Bay-Delta. The impacts of the drought in 2014 are illustrated, a drought that is perceived by farmers to be, in part, a regulatory drought based on allocation decisions. The article concludes with recommendations that disentangle agricultural water allotments from the health of the San Francisco Bay-Delta.

California and Central Valley agriculture

California has a variety of climate and land use zones. The natural diversity of the state allows for a diverse agricultural industry to thrive. Most agricultural production occurs in the Central Valley (consisting of the Sacramento Valley in the north and the San Joaquin Valley in the south). California produces nearly half of the US-grown fruits, nuts, and vegetables and nearly a quarter of the nation's milk and cream (Howitt et al. 2014; California Department of Food and Agriculture 2014). In addition to being the highest agriculture-producing state in the nation, California is significant to global food supplies as the world's fifth largest supplier of agricultural products (California Department of Food and Agriculture 2014). Innovations in irrigation, mechanization, labor structure, plant breeding, and inputs such as pesticides and fertilizers, as well as two major water projects (state and federal) have enabled this enormous and diverse productivity (Center for Urban Education about Sustainable Agriculture 2005).

The agricultural industry has become a significant foundation to the California economy. The value of farm products multiplies as it travels through the economy because the raw product harvested from the farm is then processed, marketed, shipped, and sold, which creates more jobs, labor and property income, and indirect business taxes in the state (University of California Agricultural Issues Center 2009). For instance, almond, walnut, and pistachio exports account for approximately $4.7 billion in crop value, yet associated economic multipliers raise that figure to nearly $20 billion. Export-based farm and port employment created by these three crops totaled

Table 1 Central Valley Project water allocations (2014 and 2015)

Contractors	Percent supply	
	May 13, 2014	February 27, 2015
North of Delta		
Agricultural contractors (Ag)	0 %	0 %
Urban contractors (M&I)	50 %	25 %
Wildlife refuges	75 %	75 %[a]
Settlement contractors/senior water rights[b]	75 %	75 %[a]
American river M&I contractors	50 %	25 %
In Delta-Contra Costa	50 %	25 %
South of Delta		
Agricultural contractors (Ag)	0 %	0 %
Urban contractors (M&I)	50 %	25 %
Wildlife refuges	65 %	75 %[a]
Settlement contractors/senior water rights[b]	65 %	75 %[a]
Eastside division contractors	55 %	0 %
Friant—Class 1[c]	0 %	0 %
Friant—Class 2[c]	0 %	0 %

Source: Bureau of Reclamation 2015

[a] May be reduced if dry conditions persist

[b] In California, senior water rights are superior to junior water rights. Settlement contractors have water rights that preexisted independent of the CVP and are considered "senior" water rights within the CVP

[c] Class I water is the more reliable and schedulable ("firm") water supply. Class 2 is composed of the less reliable and often nonschedulable wet year supply, generally intended for contractors who have the capability to access groundwater or other alternative supplies

more than 62,000 jobs in 2010 (California Farm Water Coalition 2014a). Annually, agriculture generates more than $90 billion in labor and property income and indirect business taxes in California (University of California Agricultural Issues Center 2009).

California water systems

California's water system is characterized by an asynchrony of water availability and demand in space and time. The availability of water peaks in the winter in the more sparsely populated northern part of the state since the source of much of this water derives from snowmelt in the mountain ranges to the north and east of the Central Valley. Water demand peaks in the summer when there is little natural precipitation and water supplies depend primarily on surface waters fed by the melting of the winter snowpack. California's extreme climate is marked by extended periods of droughts and major floods. Nearly 75 % of the available water originates in the northern third of state, while 80 % of the demand occurs in the southern two thirds of the state (Water Education 2008). Thus, California has developed a highly sophisticated water infrastructure system that relies on storing mountain runoff in large reservoirs and moving that water through the Central Valley via a system of man-made canals, aqueducts, and pipelines, often using pump stations to boost the water into adjacent watersheds.

The Sacramento River has its headwaters in the Cascade and Sierra Nevada mountain ranges in northern California. Shasta Dam stores water that drains from the Sacramento, Pit, and McCloud Rivers just north of Redding, California. Water released from Shasta flows south toward Sacramento, where it is fed along the way by the Feather River and several small tributaries that drain the northern Sierra Nevada and Coastal ranges. The San Joaquin River drains the west slope of the Sierra Nevada range, south of Lake Tahoe. Beginning in the high Sierras, just south of Yosemite, the upper reaches of the San Joaquin are stored behind Friant Dam, which releases water into the northward flowing mainstream of the river, which is in turn fed by the Fresno, Chowchilla, Merced, Stanislaus, Tuolumne, and Calaveras Rivers as it flows through agricultural land toward Stockton and San Francisco Bay. The San Joaquin River drains a much smaller area, so the productive San Joaquin Valley requires more water than is provided by the San Joaquin River. The southward-flowing Sacramento River meets the northbound San Joaquin River just south of Sacramento, where the Sacramento-San Joaquin Delta is formed. Here, the two rivers mingle with smaller tributaries and tidal flows to form a maze of sloughs and

waterways surrounding leveed tracts and islands. The rivers' combined fresh water flows pass through the Carquinez Strait, forming the San Francisco Bay/Delta Estuary, commonly referred to as the Bay-Delta. Major water projects include the federal CVP and the California State Water Project (SWP). There are also many smaller, local projects that are tied in to the Central Valley water supply picture. Figure 1 illustrates the state's major rivers, canals, and reservoirs.

Construction for the CVP was completed in 1951. The project was designed as a means to address problems that arose from excessive water in the north requiring flood control and the growing demand for water throughout the rest of the state. In a normal year, the CVP provides about 5 million acre-feet[1] of water for farms (enough to irrigate about one third of irrigated farmland in California) and 600,000 acre-feet for municipal and industrial use (enough to supply close to 1 million households with water) (Water Education 2011). The CVP also dedicates 800,000 acre-feet per year to fish and wildlife and their habitat and 410,000 acre-feet per year to state and federal wildlife refuges and wetlands because of the passage of the 1992 Central Valley Project Improvement Act (CVPIA) (Water Education 2011). Major CVP features include Shasta Dam and reservoir on the Sacramento River, Trinity Dam, and Clair Engle Lake on the Trinity River, Folsom Dam, and reservoir on the American River, Friant Dam, and reservoir on the San Joaquin River, New Melones Dam, and reservoir on the Stanislaus River, and San Luis Reservoir, a joint federal-state off-stream storage facility. San Luis Reservoir is filled with freshwater pumped from a southern point of the Bay-Delta near Tracy and serves mostly agricultural users. It is these pumps that are the focus of this paper.

After the post-World War II population boom, challenges to California's water supply became apparent: flood management was still needed in the north, more municipal water was needed in the south, water to prevent groundwater overdraft was needed in agricultural areas, and the Bay-Delta system needed improvements. California voters in 1960 approved $1.75 billion in general obligation bonds to finance the construction of the SWP. Water supply contracts were signed between the state and local agencies throughout California. Water deliveries from the project began in 1965 (State Water Contractors 2014). The SWP consists of 22 dams and reservoirs. Water in the upper Feather River is stored behind Oroville Dam and reservoir, which has a capacity of 3.5 million acre-feet. From Oroville, water flows south to the Delta where the North and South Bay aqueducts serve communities in the San Francisco Bay area. The 444-mile-long California Aqueduct begins at the Delta Pumping Plant and parallels Interstate 5 south to the Tehachapi Mountains. To cross the Tehachapi range into Southern California, the A. D. Edmonston Pumping Plant lifts water 1926 ft to cross the Tehachapi Mountains in a series of tunnels and inverted siphons. Annual water deliveries to 29 public agency contractors that buy water from the State average 2.8 million acre-feet. About 30 % of SWP water is used for irrigation, mostly in the San Joaquin Valley, and about 70 % is used for residential, municipal, and industrial use, mainly in Southern California, but also in the San Francisco Bay Area (Water Education 2008).

Both the Sacramento and San Joaquin Rivers are subject to regulations that impact water managers' ability to divert water. Those regulations are primarily related to fish populations protected by the Endangered Species Act. As the rivers mingle in the San Francisco Bay-Delta, a unique ecosystem is created and consequently, there are even more regulatory constraints having to do with more protected species as well as Clean Water Act standards related to salinity that must also be met. Water is pumped from the Bay-Delta to the San Luis Reservoir on the west side of the San Joaquin Valley, but the operation of those pumps is in adherence to environmental regulations regarding fish populations in the Bay-Delta, like the delta smelt. Increasingly, regulatory focus in recent years has been on these pumps in the Bay-Delta; therefore, this article focuses its policy analysis on the San Joaquin Valley and the water exports from the Bay-Delta pump.

Climate change and California water

California water management is already challenged by the demands of agriculture, urban growth, and environmental enhancement. Global climate change will likely further reduce those supplies (California Climate Change 2006; Tanaka et al. 2006; Bittleman 2007). Climate change is expected to increase the amount of water flowing into Central Valley rivers in the winter and reduce water flows in late spring and summer. Despite often major differences in their other results, this pattern is common to all climate models. The consequences are straightforward: Rising temperatures increase the amount of winter precipitation falling as rain rather than snow, which decreases the Sierra snowpack. The warmer temperatures cause the snow to melt earlier in the season. Ultimately, the result is reduced runoff in late spring and summer for river systems that are heavily dependent on snowmelt. Climate change is not just something to plan for in the future; it is happening now and is decreasing the California water supply through diminished runoff volume (Roos 2012).

The 2013–2014 winter snowpack was only 15–17 % of normal, which left the entire state in some state of drought, the third year of such conditions for many areas. As of October 2014, 58 % of the state was under "exceptional" drought conditions—the most serious of the US Drought Monitor categories. Another 24 % of

[1] An acre-foot of water is the volume contained in one foot of water spread over one acre and is equivalent to 326,000 gal.

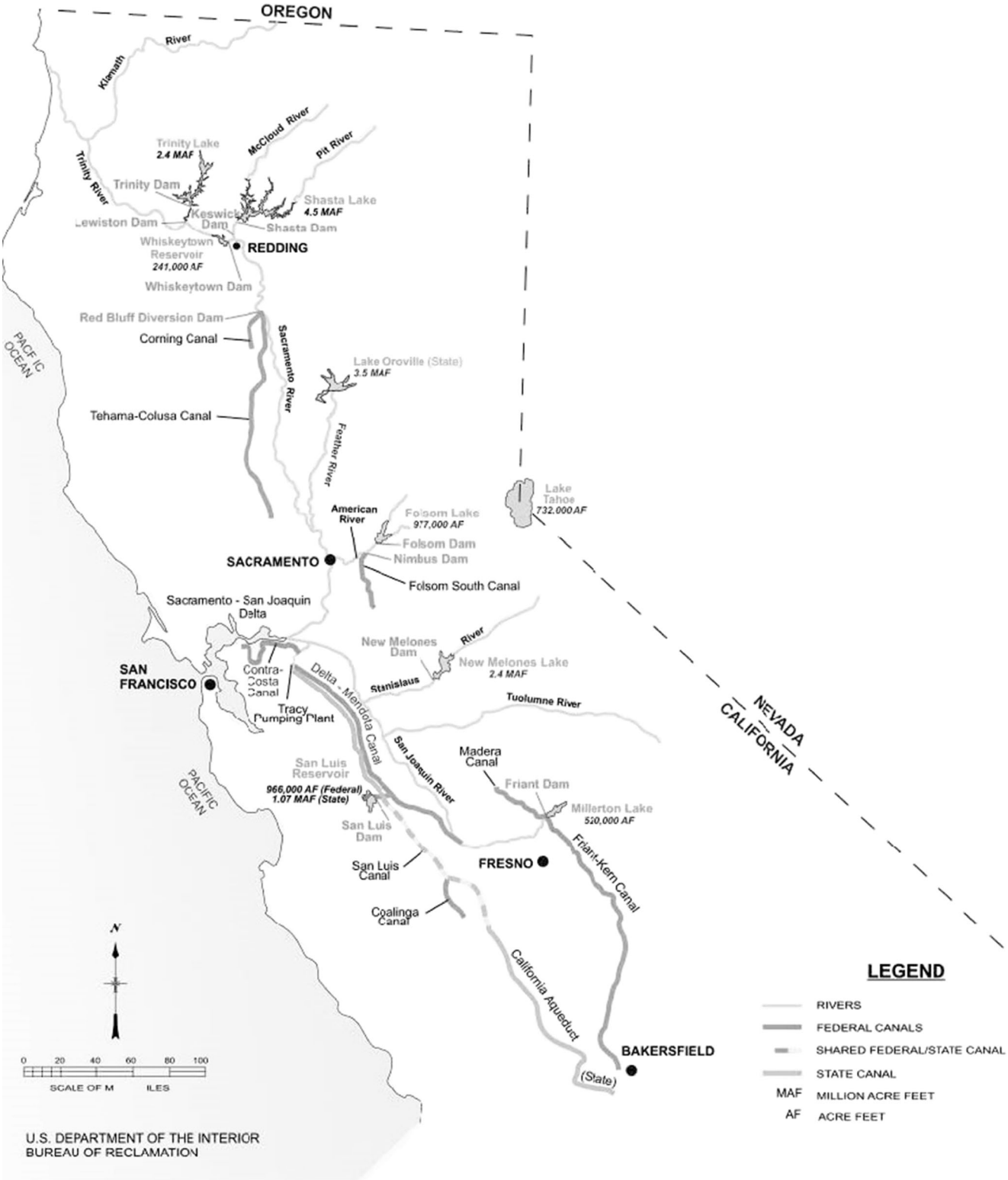

Fig. 1 California rivers, dams, lakes, and canals. Source: Bureau of Reclamation 2011

the state was experiencing "extreme" drought conditions. Certainly, nature plays a role in the water crisis that has developed in California; however, a significant cause for the lack of available water for agriculture is the complicated regulations that determine water allocations for different user groups.

Competing demands for water

According to the most recent California Water Plan—a periodic assessment and inventory report and not a regulatory directive—applied water use for the entire state of California is divided among urban (11 %), agricultural (41 %), and environmental (48 %) uses during an average water year (California Department of Water Resources 2013). Population growth is a major factor influencing water demand. From 1990 to 2012, California's population increased from 30 million to more than 38 million. The California Department of Finance projects that this trend means a state population of roughly 51 million by 2050 (California Department of Water Resources 2013). Population growth means a higher demand for urban water, but additional people also need food, which—if sourced from California farms—either leads to an increase in the agricultural water footprint or a decrease in exports.

California has the second most irrigated acreage in the USA, with only Nebraska irrigating more. California's almost 8 million irrigated acres are dedicated to a wider diversity of crops than Nebraska—more than 400 commodities (California Department of Food and Agriculture 2015; United States Department of Agriculture 2013). California farmers are some of the most innovative and efficient water users in the country. Mount (2011) noted a decline in agricultural water use between 1960 and 2005, and the California Farm Water Coalition (California Farm Water 2014b) also reported that farmers applied 14.5 % less water from 1967 to 2007 (31.2 million acre-feet in 1967 vs. 26.7 million acre-feet in 2007) while registering an 85.4 % increase in gross tons of harvested crop production. Within the last decade, $3 billion were spent (between 2003 and 2013) to increase efficiency of irrigation systems on 2.4 million acres (California Farm Water 2015).

The San Francisco Bay-Delta estuary is the largest on the West Coast and supports more than 750 animal and plant species. An estimated 25 % of all warm water and anadromous sport fish and 80 % of the state's commercial fishery live or migrate through the Delta (United States Department of the Interior et al. 2014). Populations of several native fish have declined because of a combination of entrainment in pumping facilities, poor water quality, limited food supply, lack of habitat, and nonnative species that compete for food. Six fish species in the Bay-Delta ecosystem are either already protected, or are being considered for protection, by state or federal Endangered Species Acts. These species of concern include delta smelt, winter-run and spring-run Chinook salmon, steelhead, longfin smelt, the Sacramento splittail, and the Green sturgeon. Smelt and splittail are considered indicator species at the base of the aquatic food web that gauge the health of the overall ecosystem. Salmon and steelhead are important fisheries that form the basis for other economies, but those benefits may accrue far from the rivers and estuaries that serve as nurseries for those populations. A portion of the water captured in upstream SWP and CVP reservoirs for release in drier, summer months is mandated by court order and state and federal agencies to flow through the Delta and San Francisco Bay, ultimately to discharge in the Pacific Ocean as a means to maintain a healthy aquatic ecosystem and to support these listed fish species.

Farmers in California's Central Valley feel the competition for water is most strained between agricultural needs and ecological needs due to the increased regulation of their water supplies over the past 25 years at the point of the Bay-Delta export pumps. Operating the pumps can impact fish population by changing the flow of the water. Proponents for curtailing pumping believe it will reduce the number of fish entrained in the pumps, improve water quality, and enhance fishery habitat. However, despite the reduction in pumping that has occurred, the native fish populations have not recovered.

Regulatory focus of Bay-delta environmental challenges

Water users in the Central Valley at one time had a fairly assured sense—early in the year, before planting and other farm management decisions needed to be made—of what their water supplies would be for the upcoming year. At the beginning of the year, the Bureau of Reclamation and the California Department of Water Resources (DWR) issues a water supply forecast and anticipated allocations for the various state urban, agricultural, and environmental water users based on snowpack in the mountains and anticipated weather conditions. However, in recent years, those once-reliable forecasts have been complicated by new regulations, litigation, and agency administrative directives. Farmers now regard water allocations with a sense of uncertainty which has destabilized agricultural decision-making and profitability.

Since 1977, a multitude of government regulatory and policy decisions have reduced the average water supply for CVP South of Delta agricultural service contractors (farmers and ranchers in the San Joaquin Valley who receive water from the CVP) from 90 % of their contracted deliveries to 40 % of their contracted deliveries. In short, state and federal regulations have reduced water supply availability. State and federal regulations are summarized in bullet points below that impact the export of water from the San Francisco Bay-Delta. With each policy decision, more water was allocated to in-stream use and away from other uses, such as municipal and agricultural. The reduction in agricultural water deliveries as they correspond with policy decisions are depicted in Figure 2. Note that the first bar represents years 1952–1990, when there was a sense of reliability and certainty from farmers regarding

their water contracts. The deliveries decrease as policy actions are made. [2]

- 1978 State Water Resources Control Board Decision 1485—this state water rights decision required SWP and CVP to meet Delta water quality standards.
- 1991 ESA/Winter Run Salmon Temperature Control—state orders and a federal biological opinion for winter-run Chinook salmon required CVP operations to meet specific temperature criteria in the upper river.
- 1992 Federal CVPIA—allocated 800,000 acre-feet of agricultural and urban water annually to the environment, plus another 410,000 acre-feet per year to state and federal wildlife refuges and wetlands.
- 1994 ESA/Delta Smelt Biological Opinion—the first of a series of biological opinions issued by the US Fish and Wildlife Service (USFWS) intended to avoid jeopardizing the continued existence of the Delta smelt. The focus of the "reasonable and prudent" alternatives to the coordinated export operations of the CVP and SWP has been increased regulatory restrictions on water exports.
- 1995 Water Quality Control Plan/Clean Water Act—the State Water Board primarily assigned responsibility for meeting Delta water quality objectives to the SWP and CVP.
- 1997 CVPIA (b)(2)—the CVPIA includes an Anadromous Fish Restoration Program that seeks to at least double the natural production of anadromous fish in Central Valley streams in the long term. Section 3406 (b)(2) provides 800,000 acre-feet of CVP water to use, in part, to achieve the fish doubling goal. Since 1993, (b)(2) water has been dedicated and managed annually for fish since the USFWS believes increased instream flows and export reductions at critical times have helped protect delta smelt, salmon, and steelhead in the Delta (Dealy 2009).
- 2000 Trinity River Restoration Plan—reduced the amount of CVP water diverted from the Trinity River watershed to the Central Valley, in an effort to provide flow-driven fishery restoration actions in the Trinity system.
- 2008 Delta Smelt Biological Opinion—the federal government issued a rewritten management plan for Delta smelt, declaring that Bay-Delta water operations must be dramatically altered to protect the imperiled fish.
- 2009 Salmon Biological Opinion—federal biologists and hydrologists concluded that water pumping operations in the CVP and SWP should be changed to ensure survival of salmon, steelhead, green sturgeon, and killer whales, which rely on salmon runs for food.

Media accounts of the drought in 2014 often compare the year to 1977 when the state experienced its worst recorded drought (Jorgensen and Pearce 1978). Figure 3 demonstrates that while stored water in April 2014 was 1.74 million acre-feet more than in 1977, releases from storage were about the same (San Luis and Delta Mendota Water Authority, 2014). Regardless of the similarity in release volumes, the total inflow into the Delta was actually nearly 1 million acre-feet greater in 2014 and the total Delta outflow (to the Pacific Ocean) was nearly 1.5 million acre-feet higher in 2014 than 1977.

Figures 2 and 3 strongly support farmers' claims that the 2014 drought is at least in part a "regulatory drought." Despite having less water in storage in 1977, more water was delivered to urban and agricultural users then than in 2014, meaning that the reductions in water exports from the river systems was a result of policy decisions rather than a reflection of the current drought.

Concerns of California farmers and ranchers

As demonstrated in Fig. 2, much of the water that has been directed away from Central Valley agriculture has been due to concerns regarding ecological functions in the state's rivers, wetlands, and the San Francisco Bay-Delta. A growing concern to Western irrigators is the focus on one stressor causing declining fish populations: irrigation diversions. In 2010, Congress directed the National Academy of Sciences (NAS) to convene a high-level, independent scientific review (National Research 2010) of federal restrictions on water deliveries affecting thousands of Western farmers and ranchers. In 2012, the NAS National Research Council (NRC) released a second report (National Research 2012) which, among other findings, observed that many environmental stressors, including water diversions, contaminants in the water, and introduced species, affect the structure and functioning of Delta ecosystems. "Interactions among stressors and between stressors and ecosystem processes are widespread and complex," reported the 2012 NRC study. The same study went on to say, "Species differ in their responses to stress. This complicates the interpretation and evaluation of the effects of stressors on the ecosystem, and makes it impossible to identify which stressor is the root cause of a certain environmental problem, or even to rank the stressors with any certainty."

In 2009, decisions made by the USFWS and the National Marine Fisheries Service contributed to water cutbacks and rationing, which impacted hundreds of communities throughout California, particularly devastating the San Joaquin Valley economy. More than 300,000 acre-feet during a 5-month period was held back due to the requirements for Delta pumping restrictions by the biological opinions rendered by federal

[2] To see corresponding precipitation for the years represented in the graph, please see the National Climatic Data Center's 2013 Annual Drought Report at http://www.ncdc.noaa.gov/sotc/drought/2013/13. There was actually a series of wet years in the early

1990s, but the graph shows water deliveries continued to decline meaning that the reduction in water delivered to farmers was due to policy decisions not statewide drought.

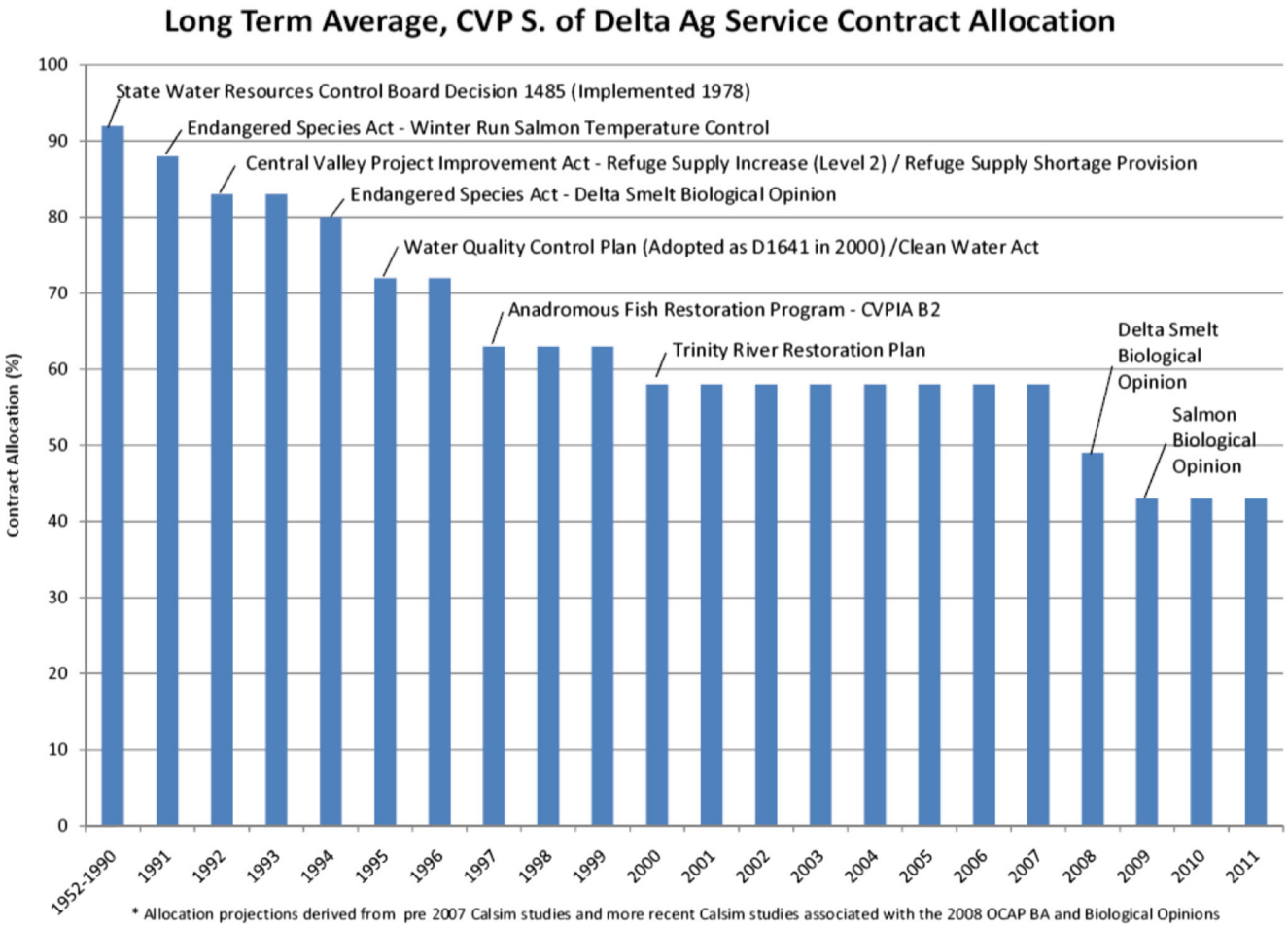

Fig. 2 Recent regulatory actions and impacts to south of Delta agricultural water contractors, Source: San Luis and Delta-Mendota Water Authority 2014. The SLMDWA graphs are not part of a report or minutes. They were prepared by a professional engineer (Tom Boardman) who works for SLMDWA and used for briefing and educational purposes

fishery agencies to protect endangered fish species (Wanger 2009).

A similar decision to focus on one stressor—the diversion of federal project water for agricultural use—was made by the same federal fishery agencies in the Klamath Basin in 2001, and that decision, and the science used by the USFWS and the National Marine Fisheries Service to support the decision, was also criticized later in a review conducted by the NRC (National Research 2004). The NAS/NRC reviewed the science after Klamath Irrigation Project water supplies from Upper Klamath Lake were cut off following the 2001 federal fishery agencies suggestions for complying with the ESA. The NRC's scientific review concluded that there was insufficient evidence to support the policy recommendation to restrict agricultural diversions from the Klamath River system as suggested by the biological opinions prepared for Coho salmon and two species of suckers. In the Klamath Basin, the federal regulators concentrated on one of the stressors contributing to the fisheries' decline and they focused on only one solution—cutting off water supplies to agriculture. A follow-up report released by the NRC Committee on Endangered and Threatened Fishes in the Klamath Basin was released in October 2003. The final NRC report clearly indicated that recovery of endangered suckers and threatened Coho salmon in the Klamath Basin cannot be achieved by actions that are exclusively or primarily focused on operation of the Klamath Project (National Research 2004).

The effects of the Klamath restrictions were immediate and far-reaching—not just losses to the economy, but also the wildlife benefits that were lost when water that was previously delivered to farms and ranches (and two federal wildlife refuges) via hundreds of miles of open channel was curtailed. In the Klamath Basin, cereal grains and other wildlife-friendly agricultural production is critical to meeting the needs of Pacific Flyway waterfowl. A California Waterfowl Association representative testified before a Congressional committee in 2001 and stated that removing wildlife-friendly agriculture from the Upper Klamath Basin would "gut our Pacific Flyway waterfowl resource by eliminating roughly half of the food base annually available to these birds (Gaines 2001)." And

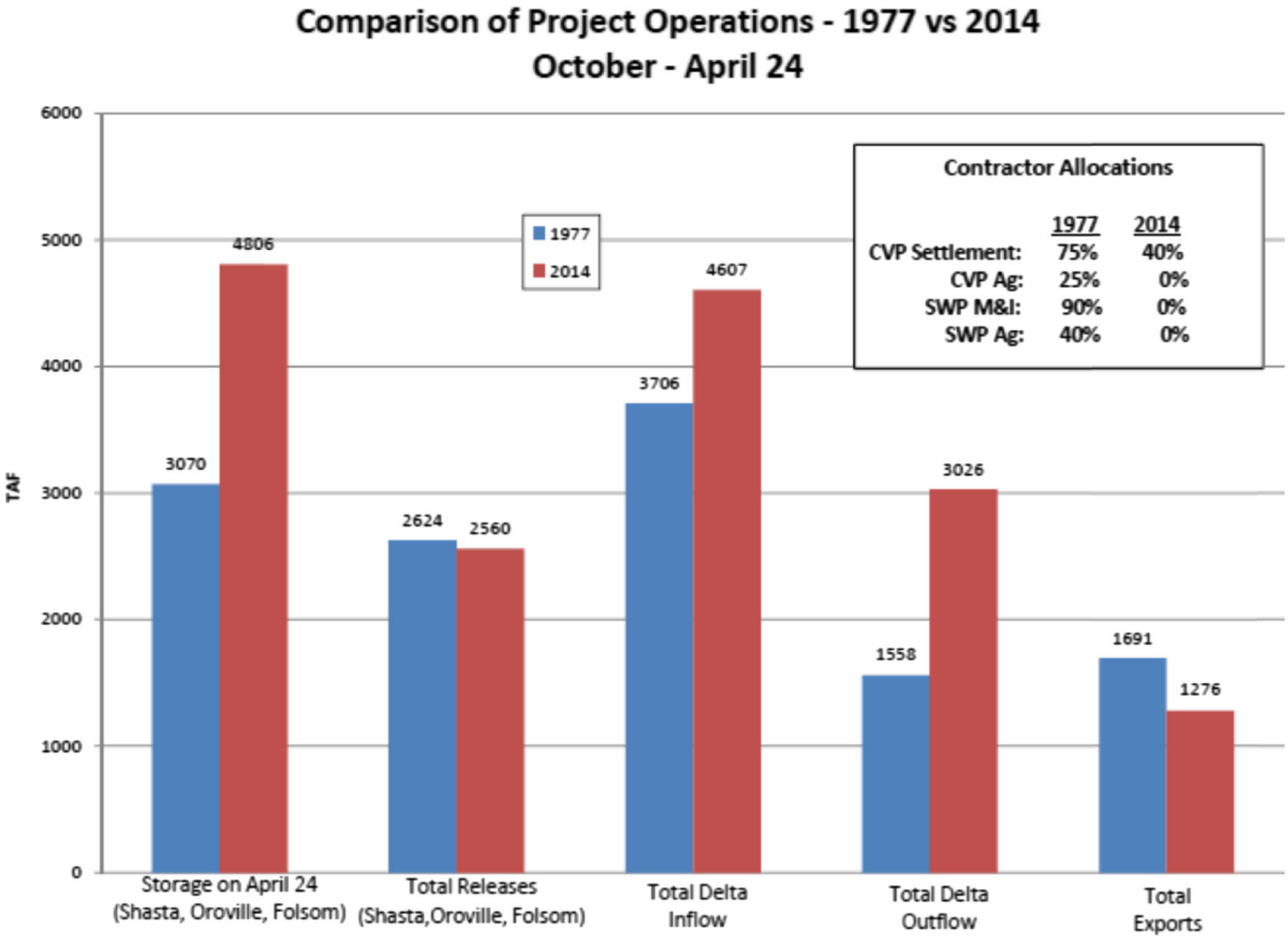

Fig. 3 Comparison of project operations in 1977 and 2014. Source: San Luis and Delta-Mendota Water Author 2014

yet, the federal regulators failed to perform a National Environmental Policy Act (NEPA) analysis before they ordered cutbacks in Klamath in 2001, a pattern that reemerged in California nearly a decade later.

Water users in California's Central Valley are concerned that in a fashion similar to the Klamath Basin, the burdens of meeting species recovery will be borne by agricultural communities without accounting for the multiple stressors impacting California aquatic habitats. A watershed-wide approach to species recovery—one that addresses all the stressors to fish—is essential to improving the environment and saving local economies. Yet, the agencies continue to focus on controlling lake and river levels, and the fish they aim to protect remain on the ESA list, over a decade later, and the agricultural community continues to struggle with operating capital, input suppliers, and contracts for products with an uncertain water supply.

In California, the Bureau of Reclamation and the USFWS neglected to assess the impacts of the many stressors affecting the health of the Delta and failed to develop a NEPA analysis to justify their actions of consistently reducing exports at the pumping station in the Bay-Delta. US District Judge Oliver Wanger (2010), in *San Luis and Delta-Mendota Water Authority and Westlands Water District v. Salazar*, found that the federal government's science did not prove that increased pumping from the Delta imperiled the smelt. Judge Wanger stated that a full NEPA analysis was not completed and directed the federal fisheries agencies to revise the biological opinions for smelt and for salmon. Judge Wanger's decision was overturned in the Ninth Circuit Court of Appeals, but the appellate court did affirm the judgment of the lower court's decision that a full NEPA analysis was needed. To date, water users await to see how new biological opinions develop in the wake of these judicial decisions.

The increasingly complex regulatory structure in California, and the increasingly expensive and protracted processes which this structure encourages, make obtaining and sustaining water supplies increasingly difficult for both agricultural and municipal users alike. For the farmer or rancher, the current federal water allocation and reallocation schemes in California and other areas of the West often create chaotic economic conditions, a sense of disillusionment and resignation, and uncertainty (Keppen 2005). Nowhere is the uncertainty of

water supplies greater than in the San Joaquin Valley from the CVP.

Impacts from 2014 Central Valley water management actions

For agricultural water users depending on federal CVP water supplies, the 2014 drought impacted different parties of the Central Valley in varying degrees. Table 1 shows that junior agricultural water rights holders in both the Sacramento and San Joaquin Valleys were allocated none of their contracted water while senior water holders had a quarter (or more) of their deliveries withheld. Much of the water was not kept in the reservoirs to be rationed later in the drought. Water that was contracted to agricultural users and supported rural communities was reallocated to meet flow requirements and water quality standards for the Bay-Delta. Figure 2 shows the changing priorities given to environmental uses of water, and Table 1 shows how wildlife refuges are given the same priority of allocation as senior water rights holders. A 2014 socioeconomic forecast was conducted by the University of California Davis (UC Davis) Center for Watershed Sciences at the request of the California Department of Food and Agriculture (Howitt et al. 2014). The UC Davis researchers used computer models and the latest estimates of State Water Project, federal Central Valley Project, and local water deliveries and groundwater pumping capacities to forecast the economic effects of the 2014 drought. The June 2014 report found that reduced surface water deliveries were estimated to total 6.5 million acre-feet of water or 32.5 % of normal water use by Central Valley growers. The lack of surface water to such a productive agricultural region has detrimentally impacted groundwater use, the economy of those communities as well as the state and has the potential to increase food prices.

Roughly one third of California's water supply in a normal year comes from groundwater (California Department of Water Resources 2003). Its usage can increase to 40 % or more during drought years. California leads the nation in groundwater withdrawals, pumping about 14.5 million acre-feet annually, according to the California DWR (2003). The 2003 update[3] on California's groundwater resources estimated that statewide groundwater overdraft—in which the amount of water withdrawn by pumping exceeds the amount that recharges a basin—is between 1 million and 2 million acre-feet annually (2003). Generally, the water removed from storage may be replaced by precipitation, stream leakage, excess applied irrigation water, artificial recharge, or any combination of the above. However, the withdrawals also have caused the permanent loss of storage by the inelastic compaction of fine-grained sediments. Other problems associated with overdrafted basins include lower water tables and increased energy costs for pumping, land subsidence, dry wells, contamination from seawater intrusion or toxic contaminants, and reduction in storage capacity of some basins.

A US Geological Survey study of the Central Valley, during the simulation period (1961–2003) recently, concluded that "in typical years, the average annual net loss in groundwater storage is about 1.4 million acre-feet. Even though volumetrically, wet years exceed dry years, in terms of changes in storage, overall water is being removed from storage (Faunt 2009)"

In the absence of once-reliable surface water supplies, many of California's farmers in 2014 were forced to rely on pumping an estimated 5 million acre-feet of groundwater from underlying aquifers. Using groundwater is an expensive alternative since there is cost associated with both the drilling of deeper wells and the pumping of groundwater to the surface. A UC Davis study (Howitt et al. 2014) reported that the 2014 drought resulted in $450 million in additional costs for groundwater pumping and an estimated $800 million in increased energy costs. The study further observed that non-floodplain regions are now becoming susceptible to flooding in some cases due to groundwater overdraft and subsidence. Pumping too much water out of the aquifers can cause the ground to subside, thus reducing the aquifers' storage capacity and increasing vulnerability to flooding. Those concerns were amplified in May 2014 when a group of scientists issued a report (Amos et al. 2014) that theorized the increasing number of earthquakes in Central California is triggered in part by the heavy pumping of groundwater in the Central Valley. Ironically, one of the original purposes of the CVP was to shift San Joaquin well users away from groundwater by importing stored surface water supplies. Now, 70 years later, farmers and ranchers are again looking belowground to replace once-reliable CVP surface water that has been reduced due to drought and redirection to other uses.

Howitt et al. estimated the 2014 diminished water deliveries to agriculture will impart a $1.5 billion loss to agriculture and agricultural-related industries in the Central Valley, rippling into a $2.2 billion hit to the state's economy. Economists predict San Joaquin Valley impacts associated with the drought at 17,100 jobs lost on the farm and in farm-related industries. Because much of the San Joaquin Valley is dependent on water from the Bay-Delta, a great amount of the economic damage centered there. Water shortages for agriculture most severely affected the Central Valley, with at least 450,000 acres lost to fallowing, $800 million in lost farm revenues, and $447 million in additional groundwater pumping costs.

[3] A comprehensive assessment of overdraft in California's groundwater basins has not been conducted since 1980. The California Department of Water Resources estimated that overdraft is between 1 and 2 million acre-feet annually (California Department of Water Resources 2003), but the estimate is tentative with no current corroborating data.

Additional dry years in 2015 and 2016 would cost Central Valley crop farming an estimated total of $1 billion each year (Howitt et al. 2014).

Farmers on the west side of the San Joaquin and Sacramento Valleys are also at zero percent for their Central Valley Project deliveries. The result has forced water districts to seek transfers of water that come with a price tag that can exceed 20 times the past cost that farmers paid for water (Burke 2014; Vekshin 2014; Castellon 2014). Monthly unemployment numbers were anticipated to spike as high as 40 % in rural communities as a result of zero water allocations (United States Department of Agriculture 2014). The drop in water deliveries to farmers in the Sacramento Valley in Northern California resulted in a 23 % reduction in rice acreage planted in 2014 as compared to the previous year (personal communication with Tim Johnson, Executive Director of the California Rice Commission; United States Department of Agriculture 2015).

According to an update prepared by the US Department of Agriculture Economic Research Service (ERS), the impact of the drought on food prices depends on its severity, the impact it has on production, and the acreage and planting decisions of California farmers (Economic Research 2014). For fruits and vegetables, ERS found "the immediate concern is the cost and availability of groundwater to supply the crops. Owing to higher production costs, insufficient water, or both, producers may opt to reduce total acreage, driving up prices not just this year but for years to come." While the California drought has not yet had a measurable impact on national prices for fruit or vegetables, ERS found that "major impacts from the drought in California have the potential to result in food price inflation above the 25 year historical average of 2.8 percent."

ERS noted that droughts in California are generally associated with higher retail prices for produce, but the effects do not occur immediately. "At this point, it is too soon to discuss the extent to which this is likely to happen throughout California," the ERS report concluded. For example, because drought can impact the availability of alfalfa, a key feed source for dairy cattle, milk prices could be quickly impacted, while prices of other dairy products (sour cream, cheese, ice cream) could have a delayed response on grocery shelves. While there is recent growing public awareness of food price increases in the supermarket, the anticipated hikes have not completely materialized. There are three possible explanations for this (National Public 2014):

- First, some farmers have temporary water supplies; they are pumping it out of aquifers or paying unprecedented prices to buy water from neighbors. Commodity prices remain the same, so when water becomes more expensive, it is the profits to the farmer that are impacted.
- Second, agriculture in California is spread around different parts of the state. One key region is the Salinas Valley, where in June, 90 % of the lettuce in the USA is grown. Those farms have always relied on well water and do not receive surface water from California's dams and reservoirs. In the winter, produce mostly come from other areas of the Southwest. Those areas are supplied with water from the Colorado River, which fared better from a hydrologic standpoint in 2014 due to higher than normal snow runoff far upstream.
- Third, the limited amount of water available is being dedicated to crops that consumers eat directly. In 2014, less water went toward production of crops like alfalfa or rice, which are available from other places or that consumers do not eat directly. As a consequence, consumers are shielded from the drought's effects. However, the price of alfalfa increased by 40 % (Howitt et al. 2014), and as a crop that supports the beef and dairy industry, it is expected that the prices of those products will also increase.

It is possible that prices will rise during the 2015–2016 winter, due to shortfalls in production. Because more than 500,000 acres of total farmland in the Central Valley went unplanted due to water delivery restrictions, a void will be created in the marketplace for California-grown produce (Campbell 2014). In addition to the reduced production of fruit and vegetable crops, orchard owners are also facing decisions on whether to rip out trees, use deficit watering that will keep the trees alive but sacrifice crop production for a couple years, or risk dependency on expensive groundwater wells in hopes that profits will cover the extra expense. An unpublished paper prepared by California Citrus Mutual and circulated through the California state government leadership estimated that 40–50,000 acres of citrus fruit, representing $3 billion for the San Joaquin region, would be lost. David Doll, a University of California pomology farm advisor in Merced County, said, "California almond growers generally cycle through 30,000 to 40,000 acres of replanted trees each year, which is between 4 and 5 percent of total acreage. Because of severe water shortages this year (2014), he estimated removals could increase to 50,000 to 60,000 acres, or 6 to 8 percent (Souza 2014)."

Farmers with no water cannot increase commodity production, regardless how high prices rise. Likewise, producers whose crops and/or livestock are ravaged by disease cannot increase production unless or until cures are found. While we cannot control nature, we can control the regulatory component that is most certainly contributing to the 2014 drought in California.

Recommendations

Central Valley water users are dependent on the uncertain operations of the export pumps in the Bay-Delta, which are in turn dependent on management decisions aimed at protecting fish populations. As a means to decrease the

dependency on those export pumps and provide more effective use of water for both agricultural protection and species protection, the authors recommend a comprehensive, science-based management plan for the Bay-Delta and an increase in water storage capacity.

Need for a cooperative settlement generated by stakeholders

Examining California's Bay-Delta ecosystem with a system approach suggests a need for resiliency to be built into the complex system that is based on a scarce resource that is vulnerable to climatic changes. If the "solution" is reductionist (i.e., focusing on only a portion of the drivers of the problem) then the result will be unlikely to build resilience. Simply denying water to farmers to provide more water for the Delta ecosystem only focuses on one driver of the declining fish populations. Mount et al. conclude in their 2012 report that trying to maintain the status quo of water management in the Bay-Delta is the least likely avenue to successfully managing the native biodiversity. There is a need to assess what interventions are needed in order to support the Delta's ecological functions and whether we have an adequate understanding of system interactions (i.e., both the benefits of maintaining the ecology of the Delta for agriculture and urban residents, as well as the contribution of reducing agriculture and urban consumption for maintaining the Delta ecology) to support the regulatory interventions (Hallie Eakin[4], personal communication 2014).

There is no clear correlation between the reduced pumping from the Delta and populations of protected fish species. The Delta smelt and winter-run and spring-run Chinook salmon, which are listed under the ESA, have shown little improvement in total spawning numbers since federal fisheries agencies have restricted agricultural water diversions intended to protect these fish (California Department of Fish and Game 2014a, b; Pacific Fisheries Marine 2014).[5] As there is not a clear correlation that pumping restrictions are directly linked to recovery of targeted species, perhaps factors other than irrigation withdrawals are impacting the fishery of the Bay-Delta, a finding that is consistent with 2012 NRC report. It is important to understand that it is not just a certain amount of water that is needed to flow through the Bay Delta to create a suitable habitat for native fishes. The entire Bay-Delta region has been changed including the physical geography, water quality, and biodiversity of the food web, in addition to the flow regime. Improved flow regimes do not simply mean more water flowing, but variable flows that reflect the seasonal and interannual variations of California's Mediterranean climate (Mount et al. 2012). The timing and velocity of flows in turn influences salinity and temperature gradients. Opportunities exist to mitigate multiple stressors and still provide water for agricultural users.

Mount et al. (2012) group the many stressors that impact the Bay-Delta ecosystem into five broad categories: discharges altering water quality, fisheries management activities, flow regime alterations, invasive species, and physical habitat disruption and removal. Pumping water for export to the San Joaquin Valley only fits with one of these categories. The NRC (National Research 2012) report similarly found that "the large number of stressors, their effects and interactions lead to the conclusion that efforts to eliminate any one stressor are unlikely to reverse declines in listed species." Still, the agencies appear to be focused on controlling export pumping levels, even though "opportunities exist to mitigate or reverse the effects of many stressors," as noted by the NRC (2012). Mount et al. (2012) conclude that collective actions involving all stakeholder and interest groups are required. A long-term strategy is needed to secure California's water supplies and improve the ecosystem of the Sacramento-San Joaquin River Delta, one that would contribute to the conservation of fish, plants, and wildlife in the Delta as well as provide water for export to the San Joaquin Valley.

The competitive nature of water issues creates antagonistic approaches to water management and is an inherent obstacle to collaborative solutions. While competition seems inevitable when managing a scarce resource, the competitive framing of the issue undermines the potential to see how different and perhaps more innovative uses of water can be potentially compatible or even synergistic (Hallie Eakin, personal communication, 2004). Bay-Delta water management is sorely in need of a comprehensive, integrated water management strategy that provides water supply reliability while improving the Bay-Delta ecosystem. One such approach underway is the Bay Delta Conservation Plan (BDCP), which has been considered as part of California's overall water management portfolio. It is being developed as a 50-year habitat conservation plan with the goals of restoring the Bay-Delta ecosystem and securing California water supplies. While the BDCP's fate is uncertain—in part due to the departure from original

[4] Hallie Eakin is a Senior Sustainability Scientist at the Julie Ann Wrigley Global Institute of Sustainability and Associate Professor at the School of Sustainability at Arizona State University.

[5] The California Department of Fish and Game (DFG) compiles annual population estimates of Chinook salmon in the Central Valley. The GrandTab report is a compilation of sources estimating the late-fall, winter, spring, and fall-run Chinook salmon total populations for streams surveyed. The Fall Midwater Trawl Survey (FMWT) is also conducted by the California Department of Fish and Game and is used to assess Delta smelt populations. Also, the Pacific Fisheries Management Council provides similar data that demonstrate winter-run and spring-run salmon populations continue to struggle.

objectives and because of the fracturing of network relationships between cooperating parties caused by the drought crisis—the founding philosophy of science-driven collaboration is a necessary ingredient essential to the success of a long-term Bay-Delta solution.

The BDCP seeks to identify an alternate way of routing freshwater supplies from the Sacramento River to the state and federal water facilities. Currently, the operation of the export pumps in the south delta, and the water users they represent, is dependent on the conditions of a declining ecosystem. Rather than using the Delta as the primary conduit for water supplies, the BDCP is analyzing options to utilize multiple diversion locations (rather than the sole export diversion location at Tracy) to move water through a tunnel underneath the Delta or a canal around the Delta. Currently, the operation of the South Delta pumps varies based on the water quality of the Bay-Delta; however, with alternative locations for diverting Sacramento River water, San Joaquin water contractors can be assured water deliveries that are not dependent on Bay-Delta. By providing operational flexibility in the delicate ecosystem and taking steps to restore habitat, the Bay Delta Conservation Plan can create a healthy, sustainable Delta environment, protect water supplies from earthquakes and other natural disasters, and provide reliability of deliveries to water contractors.

The recently signed Klamath Settlement Agreements (Proposed Upper Klamath Basin Comprehensive Agreement 2014) provide an example of how a cooperative agreement can be reached through stakeholder cooperation. These landmark agreements, signed in 2010 by more than 40 parties and expanded in 2014, would resolve conflicts previously discussed over water rights, fisheries, dam-relicensing, and other issues and end decades of litigation and division. Under these agreements—which require Congressional authorization—Klamath Basin farmers and ranchers would receive increased water supply security while Klamath River tribes and other parties would obtain restoration of fisheries, including the future removal of four dams. Customers in the West served by the privately owned hydroelectric dams are protected from uncertain costs of Federal Energy Regulatory Commission relicensing conditions. From the standpoint of irrigators reliant upon federal water projects in other parts of the West—such as the CVP water users in California—the settlements could provide a template to follow in order to provide more predictable water supplies for farmers in dry years.

Water storage

While this paper focuses on the drought from a regulatory perspective, more water storage options would also make the whole system more flexible and resilient during times of extended drought. A 2008 University of California study (Roland-Holst and Kahrl 2008) assessed climate risk and response in California and found, "Even in the most optimistic scenario, Sierra snowpack, a major source of water storage for the Central Valley, is projected to shrink by 30 percent by 2070–2099. All scenarios show significantly increased water flow in the winter, and decreased flow in the spring and summer, when water demand is highest." With a decrease in the natural storage of mountain snowpack and an expectation of increased heavy downpour events, storage infrastructure needs to be developed to store rain water and runoff for years with surplus precipitation. During the 2010–2011 winter, excess water was released rather than stored because of limited storage capacity. However, if that surplus water was put into storage, it could be supplementing restricted water deliveries now.

There are two potential California surface water storage facilities that merit serious discussion: Sites Reservoir and Temperance Flat Dam. Sites Reservoir is a proposed offstream storage facility in the Western Sacramento Valley, which has been recognized by the California DWR as one of the most cost-effective and environmentally beneficial new facilities under consideration. Importantly, Sites could greatly increase reliability of water supplies by reducing direct water diversions on the Sacramento River during critical migration periods (California Department of Water Resources 2015). Temperance Flat Dam would be a new structure constructed on the San Joaquin River, above Friant Dam, which would provide much needed water supplies and hydroelectric power (California Department of Water Resources 2007). If Sites and Temperance Flat were online in California, their additional yield and flexibility would have been utilized in the years preceding the 2014 drought. The estimated total average annual yield ranges from 635,000 acre-feet to 823,000 acre-feet per year, depending on the benefit emphasis of each project. These two projects are notable in that they are gaining support via bipartisan Congressional sponsorship of legislation introduced in 2014 (H.R.4300—Sacramento Valley Water Storage and Restoration Act of 2014 and H.R.4127—Upper San Joaquin River Storage Act of 2014) and the 2:1 passage of California Proposition 1, which includes substantial funding provisions for the development of new storage projects.

Since the passage of Proposition 1, some interests in California have argued that new "storage" projects should be developed underground, using available aquifer capacity. While these sorts of projects are applicable in certain locales, proponents of "aboveground" projects argue that properly designed and constructed surface storage projects will provide better water management flexibility and satisfy more purposes, such as flood control, hydropower generation (groundwater storage projects consume energy, rather than generate it), recreational opportunities, and downstream environmental flow augmentation.

Water conservation (i.e., "demand management") is often seen as the solution to water supply issues, and those efforts should continue. As previously noted, farmers are already

investing in upgraded irrigation systems. However, water saving cannot be expanded indefinitely without reducing acreage in production.

Conclusion

The whole California water system is very fragile given the diversity of the demands on it and how the ecology and hydrology of the Central Valley has been transformed over the twentieth century. Water law in the West is based on prior appropriation, which means it is founded on historical use. Historically, water resources were primarily developed and used for agricultural production. When new regulations override those historical practices, the foundation of water policy is destabilized creating fear and uncertainty, particularly among the senior water rights holders, which are typically farmers. Water used for agriculture in the Central Valley and the western USA is increasingly seen as a potential supply for growing urban and environmental needs (Western States Water 2008; Family Farm 2008). While acknowledging that environmental water needs are important and have been historically ignored, it is also important to note that California communities have been based on water agreements that predate their understanding of ecosystem services. A report produced at Fresno State University (Canessa et al. 2011) states that transferring water from agriculture will require fallowing land, impacting a major industry in the state, food availability throughout the world, and the economic well-being of Californians. A spring 2014 poll by the *Los Angeles Times*, most Californians appear indifferent to the drought with only 16 % of those surveyed in California saying it has personally affected them in a measurable way. One reason for the indifference is that—outside of rural, agricultural-based communities—most people in population centers in California and elsewhere in the USA have enough water. However, Americans currently enjoy the luxury of being able to spend a very low percentage of their disposable income on food (Pacific Northwest 2013).[6] A continual trend in diverting water from agriculture may come at the cost of realizing a higher cost for our food supply and selection.

The California food production system has been shown to be vulnerable to the environmental policies meant to manage the Bay-Delta ecosystem. A mediated settlement, representing key stakeholders, is needed to ensure full adoption and compliance of new policies so time, money, and water are not wasted during ongoing litigation. The Bay-Delta is currently managed with the majority of the state's water going to support fisheries that may not require more water but better management of other stressors to the system like pollutants and invasive species. However, discussing the ESA makes stakeholders nervous and discourages cooperation. Mediated conflict resolution, rather than litigation, can allow regulatory flexibility, an open discussion of options, and collaboration.

A goal of this paper is to offer up recommendations that environmental scientists and teachers can consider as they pursue research, education, policy and community action, and other means to make the food production system more resilient and less vulnerable. Obviously, the Central Valley conundrum is incredibly complex, but it is by no means an isolated occurrence. Similar competition for water use occurs throughout the world, let alone the American West. As the saying goes, "Food grows where water flows," and lessons learned in the Central Valley regarding policy innovation, stakeholder cooperation, and technology application can be useful in other regions with the hope of making food production more resilient and water use more efficient.

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