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Delta Dilemmas: Reconciling Water-Supply Reliability and Environmental Goals

Richard Howitt

The Sacramento–San Joaquin Delta is at risk from natural forces, and with it a substantial proportion of the San Joaquin and Southern California water supply. Economic and institutional results from a new inter-disciplinary study show that a radical change in policy may be required.

Also in this issue

The agricultural and urban economies in Southern California are subject to an increasingly risky water supply through the Sacramento-San Joaquin River Delta. A large proportion of the San Joaquin and Southern California supply is routed through the Sacramento-San Joaquin Delta, located east of the San Francisco Bay Area. Most of this naturally marshy landscape has now been drained and converted into islands, many of them lying below sea level and protected by a system of 1,100 miles of artificial levees. The Delta serves as an important wildlife and habitat area; it has a significant recreational and agricultural economy, and serves as an essential conduit for water supply to the San Joaquin Valley agricultural economy and over 20 million urban dwellers in Southern California. The fragility of the Delta, as a system for water supply and fresh-water habitat, was recently brought into focus by two events: the collapse of levees around an island called Jones Tract in 2004, and the Katrina disaster in New Orleans.

This article reports on the economic and institutional aspects of a recent interdisciplinary study that examine a number of Delta alternatives. Last month, the Public Policy Institute of California (PPIC) issued a report titled, "Envisioning Futures for the Sacramento-San Joaquin Delta." The authors were Jay Lund, Ellen Hanak, William Fleenor, Richard Howitt, Jeffrey Mount, and Peter Moyle. With the exception of Hanak, a PPIC fellow, the authors are from University of California, Davis.

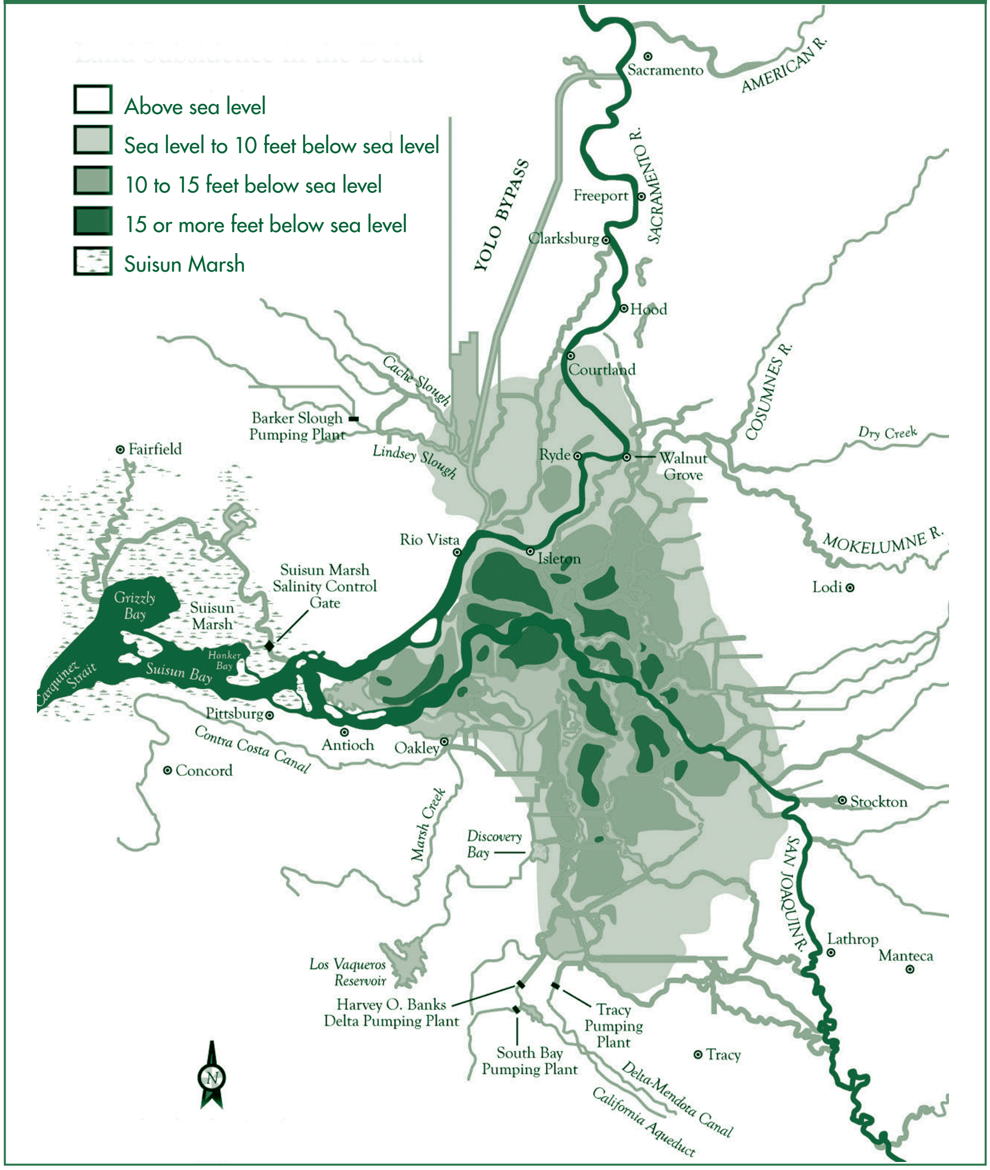
A Crisis in the Delta

The Delta is in crisis at three levels: (1) the levee system is in poor condition and fragile; (2) several native fish species are in decline; and, (3) its governing institution, CALFED, is under financial and political stress.

The increasing risk of an interrupted water supply is shown in a 2005 study by Mount and Twiss, who calculated that a combination of land subsidence, earthquakes, and global climate change effects result in a 64 percent probability of a major collapse of the Delta in the next 50 years. Areas with significant land subsidence are shown in Figure 1. The cost of supply interruption from a rapid collapse and a two to three year recovery period was estimated to be on the order of $40 billion or greater.This level of infrastructure risk seems unacceptable for the California economy.

Environmental constraints are central to Delta policy. In fall 2004, routine fish surveys registered sharp declines in several pelagic (or open-water) species, including the Delta Smelt, a species listed as threatened under the Endangered Species Act. Subsequent surveys have confirmed the trend, raising concerns that the smelt, sometimes seen as an indicator of ecosystem health in the Delta, risks extinction if a solution is not

Figure 1. Land Subsidence in the Delta



found quickly. The listing of the Delta Smelt as an endangered species introduced legal and political constraints as well as environmental concerns.

The governing institution for the Delta is also under pressure. In the mid-1990s a combined federal and state agency, CALFED, was formed to solve the impasse in Delta policy. CALFED was based on consensus politics and public funding. The stated theme was, "We will all get better together." Over its first seven years, CALFED spent approximately $1.5 billion on research and Delta improvements. The program yielded many scientific insights, but little in terms of observable improvements in the ecological health of the threatened species or water-supply reliability. As public funding dwindled, political divisions among the interest groups grew. The CALFED criteria that the beneficiary pays for private benefits ran into the familiar problem that plagues many attempts to extract private payments for what are perceived to be collective projects. As one observer wryly remarked, "The beneficiary clause should be rewritten as: 'The beneficiary pays, but not much, and not now.'" As a result of cost-allocation disputes, major Delta improvement projects were stalled by fiscal posturing. One of the problems with the CALFED requirement for consensus within interest groups was that the set of possible solutions examined was restricted. Only those solutions that maintained the 70-year policy of a year-round, fresh-water Delta were acceptable for further analysis. Since the current study was independent of state or federal funding we were able to examine a much wider set of alternative policies, some of which resulted in fluctuating salinity levels in the Delta. Three criteria were used to assess alternative policies: water supply, the environment, and the economic cost and impact of the policies. In addition, the study adopted an approach that focused on the trade-offs available rather than a consensus among all interest groups.

Study Findings

Findings from the study can be categorized as physical, institutional, and economic. This article focuses on the institutional and economic aspects.

A key physical finding by the participating environmental scientists, is that a Delta with fluctuating salinity levels would be more hospitable for native species than the long-standing current policy of maintaining constant fresh water. A serious environmental problem in the Delta is the disruption of the food chain by invasive fauna and flora. Unlike many studies, both the environmental and economic criteria coincide on their preference for alternative Delta solutions. In this study, the usual tension between environmental and economic assessments has yet to arise.

The institutional paralysis that has recently gripped the CALFED process is a predictable outcome of blocking coalitions once the common property resource of public funding is removed. The study group recognized that for most solutions, not everyone would get better together and trade-offs will have to be made. However, for some public goods, we propose mitigation mechanisms. For example, easements to compensate for potential flood damage can be negotiated in advance of the event, rather than in the frenzied atmosphere of a flood event. The state faces an interesting policy problem regarding Delta mitigations. If enough parties cannot agree on a more sustainable solution, nothing is likely to be done. The Delta will then likely fail catastrophically, incurring major emergency expenses, plus restoration and remediation expenses under very unfavorable conditions. By investing in mitigations, some economically minor compensation costs (relative to California's $1.5 trillion/year economy) might be used to catalyze agreement on better long-term solutions for the Delta.

Given the reduction of public funding and the impotence of the "beneficiary pays" declaration, any feasible Delta solution will have to have a different method to raise funds from the many private beneficiaries. The infrastructure requirements of most of the alternatives under consideration have the usual decreasing marginal cost structure of public projects. The standard approach for constructing water resource projects is to optimally size projects based on engineering criteria, and then try to negotiate cost recovery from private agents. Understandably, this approach has a poor history based on perverse incentives. The study defines two principles for an alternative financing approach. First, project sizing and financing decisions must be made simultaneously. Second, given decreasing marginal costs and widely different elasticities of demand for water supplies, some form of differential pricing is required. For example, airlines use differential pricing to fill their aircraft. What is not yet clear, is how subsequent trading of capacity rights can be combined with differential prices.

The economic results of alternative Delta policies were all expressed in terms of costs, to make them directly comparable to project costs. Any change in water deliveries or farm production is expressed as a scarcity cost and is equivalent to the reduction in benefits from water used as an input to agriculture or directly consumed by urban users. Most of the economic impact analysis was performed using two economic-engineering models: the first, termed Calvin, models the whole California water economy; the second, disaggregated to the Delta agricultural economy, is called the Delta Agricultural Production model (DAP). The DAP model was constructed for the Delta study and was notable for costs that it did not show. A field level of compilation of Delta cropping showed the initially surprising results that the agricultural islands at risk in the central and western parts of the Delta had cropping patterns that were dominated by low-value crops (Figure 2). The DAP model showed that an increase in the ambient salinity, or the loss of an island to levee failure, did not result in large impacts to the regional or state agricultural economy. The crop survey showed that the high-value crops grown in the Delta tend to be clustered in those parts with deeper soils and more predictable water supplies.

A simple analysis of the Jones Tract levee break in 2004 shows how a more flexible levee and island-rescue policy could redirect public funds. The Jones Tract levee collapsed for unknown reasons in June 2004. Decisions had to be made instantly, and the repair and restoration process was started immediately. Estimates of the total cost to the state vary, but range between $45 and $60 million. I estimate that the agricultural value of the 11,000 acres of land in Jones Tract is $28 million and, even allowing for some infrastructure costs of abandoning the island, it would seem to have been a rational use of public money to harden the levees on their inside and leave it flooded. Since it is impossible to make such calculations in real time, one of the short-term study recommendations is that Delta islands be examined for their value and restoration cost, and a "do not resuscitate" list is made of those that should be abandoned in the event of a levee break. Some of the cost of lost value may be amortized by a conditional easement on the island. Figure 2 shows some results from the DAP model that illustrate the wide range of salinity and productivity across the different Delta islands. The agricultural revenues are depicted by the size of the dark circles and vary from a few hundred dollars per acre to almost two thousand dollars per acre. The spatial distribution of salinity and crop revenues is significant. By comparing Figures 1 and 2, it can be seen that the low-revenue areas coincide with those islands most at risk due to land subsidence. Other runs of the DAP model calculated the loss in revenues from increased water salinity that can

Figure 2. The Value of Delta Crop Production

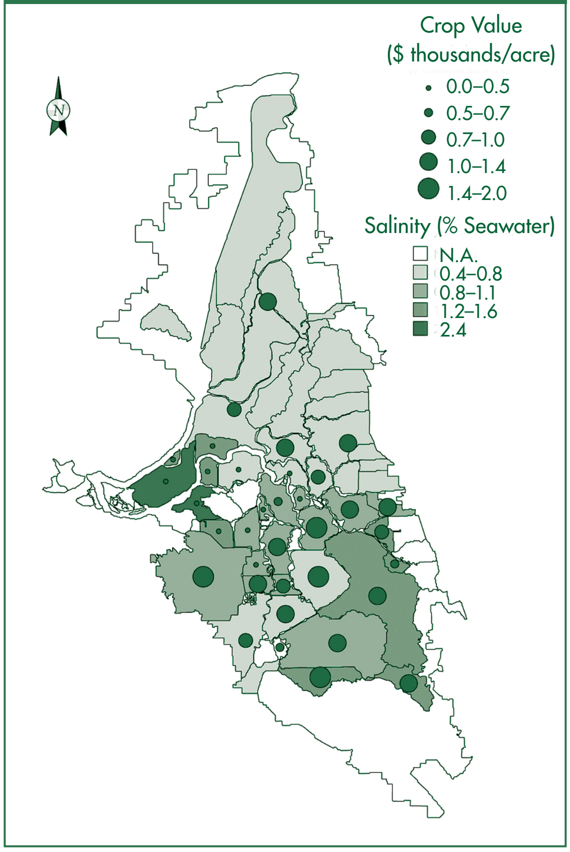


Table 1. Economic and Financial Costs of Delta Alternatives

Alternatives	Investment Costs	Annual Costs from Water or Land Reductions: Statewide Water Users	Annual Costs from Water or Land Reductions: Delta Agriculture
Freshwater Delta			
1. Levees as Usual	~ $2 billion, plus increasing costs of failure and replacement	Increasing costs as levees fail	Increasing costs from island flooding
2. Fortress Delta	> $4 billion	No additional water scarcity costs	Some land out of production from island flooding
3. Seaward Saltwater Barrier	$2–$3 billion	No additional water scarcity costs	Increasing costs from island flooding
Fluctuating Delta			
4. Peripheral Canal Plus	$2 –$3 billion	Some water scarcity costs	$70 million/year
5. South Delta Restoration Aquaduct	$2–$3 billion	Some water scarcity costs	$41 million/year
6. Armored-Island Aqueduct	$1–$2 billion+	Some water scarcity costs	$30 million/year
Reduced–Exports Delta			
7. Opportunistic Delta	$0.7–$2.2 billion in Delta and near-Delta facilities	$120 million/year	$50 million/year
8. Eco-Delta	Several billion dollars for eco-restoration + water user investments	$500 million/year	$100 million/year
9. Abandoned Delta	~ $500 million	~ $1 billion/year	$200 million/year

NOTES: Capital costs do not include possible investment needs for nonwater infrastructure (e.g., roads, rail). All alternatives except #9 (and possibly #2) would require additional investments for urban levees to provide flood protection exceeding 200-year average recurrence. All alternatives except #8 and #9 would require additional investments for ecosystem restoration. Adding finer fish screening or bank filtration to intakes to reduce fish and larvae entrainment would increase costs and potentially reduce pumping capacities for alternatives #1–8. Water-scarcity costs occur when water deliveries are less than desired. Scarcity is often managed by price, rationing urban-water use, fallowing some farmland, or curtailing recreational activities.

result from levee failure of different Delta management approaches.

The study examined nine alternative Delta policies that ranged from a complete rebuild of Delta levees, to an abandonment of the Delta to the forces of nature. Table 1 provides a condensed summary of the costs of the alternatives. It includes all the options even though the economic and financial data available were incomplete. For options 5-6, the scarcity cost cannot be assessed in advance if the proposed system of simultaneous sizing and payment is used. Further details on the sources of data and assumptions can be found in Appendix E of Lund et al. Additionally, the inflation indices used to unify the investment costs are probably understated for recent changes in land and construction costs. At this level of analysis, it appears that those options that allow for a fluctuating salinity level in the Delta provide a more reliable water supply at similar or lower costs, and also provide an improved environment for native species. Based on the three criteria of water supply, environmental impacts, and economic effects, the study concludes that the first three alternatives that require a maintained fresh-water Delta are too risky for water supply, are equally costly, and do not have environmental benefits. On this basis, the study team recommends that alternatives 1-3 be removed from consideration. Likewise, the ninth alternative of abandoning the Delta had poor environmental effects and was excessively costly for the state's economy. The remaining five alternatives all have some degree of salinity fluctuation in the Delta, and different levels in infrastructure and water-supply deliveries. Clearly there is much technical analysis to be done before a preferred alternative is selected, but the message is unavoidable that existing Delta policy should change. The examination of Delta alternatives should be viewed in terms of smaller preemptive investments that would steer the Delta toward a "soft landing" into a more stable ecological and economic state, versus the growing risk of a catastrophic failure and "crash landing" of the state's water economy.

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For more information, the author recommends the following reading:

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The 2007 Freeze: Tallying the Toll Two Months Later

Hoy F. Carman and Richard J. Sexton

This paper assesses the production losses and the resulting price impacts from the severe January freeze in California. Predictions made at the time of the freeze concerning product shortages were largely incorrect due to market adjustments in the form of revised trade flows and higher prices. Indeed, positive price effects offset much of the aggregate revenue loss from reduced harvests.

California's total orange harvest is now estimated at 37 million boxes, 39 percent lower than last year's 60.5 million boxes. Additional losses to growers that are less easily quantified include long-term damage to trees in the case of citrus and avocados.

Photo by Julie McNamara

California crop producers endured freezing temperatures from January 11-17, 2007, which led President Bush to declare a major disaster in the state. As of March 2, the state's County Agricultural Commissioners had estimated losses from the freeze totaling $1.38 billion, with the most extensive losses incurred in the major citrus- and vegetable-producing counties (Table 1).

The commodities hardest hit included citrus fruit, especially navel oranges and lemons, avocados, where the crop loss is estimated at 27 percent, strawberries, where most of the early coastal harvest was lost, and winter and spring vegetables. The winter vegetable loss was focused in the Imperial and Coachella Valleys, affecting crops such as head and leaf lettuce, broccoli, and celery. Elsewhere, e.g., in San Joaquin County, spring vegetables were damaged in their nascent state, and those losses are only now beginning to be noticed in the supermarkets.

This paper assesses the production losses and the resulting price impacts. Predictions made at the time of the freeze concerning product shortages were largely incorrect due to market adjustments in the form of revised trade flows and higher prices. Indeed, positive price effects were able to offset much of the aggregate revenue loss from reduced harvest. However, the aggregate, commodity-level analysis masks considerable variation in the distributional impact of the freeze across growers and producing regions.

Production Impacts

Estimated 2006-07 production of California citrus fruits is reported in Table 2, with comparisons to the 2005-06 crop. California's total orange harvest is now estimated at 37.0 million boxes, 39 percent lower than last year's 60.5 million boxes. Although harvesting of navels was well underway prior to the freeze, the production forecast is 20 million boxes less than last year. Further, much of the crop that was harvested after the freeze is suitable only for juice. Although the Valencia harvest is yet to begin, the USDA forecast is that it will be down 25.9 percent from last year, but other forecasts are for an even higher decline, in the range of 40-60 percent. As Table 2 indicates, reductions in harvest of a comparable percentage magnitude are forecast for grapefruit, lemons, and tangerines. Losses, however, varied

Table 1. Preliminary Crop-Loss Estimates

County	Current Loss Figure (Millions $$)	Major Impacted Crops
Tulare	418.6	Citrus Fruit
Ventura	280.9	Nursery Stock, Avocados, Citrus Fruit
Kern	178.9	Citrus Fruit
San Diego	114.7	Avocados, Bedding Plants
Fresno	104.1	Citrus Fruit
Riverside	86.0	Table Grapes, Citrus Fruit, Avocados
Imperial	77.5	Lettuce, Sweet Corn, Potatoes

Source: California Farm Bureau Federation

Table 2. California Citrus Production: 2005–06 and Forecast 2006–07

Commodity	2005-06 Production (1,000 Boxes)	2006-07 Forecast Production (1,000 Boxes)
Navel oranges	47,000	27,000
Valencia oranges	13,500	10,000
Grapefruit	6,000	4,800
Lemons	21,000	16,500
Tangerines	3,600	2,600

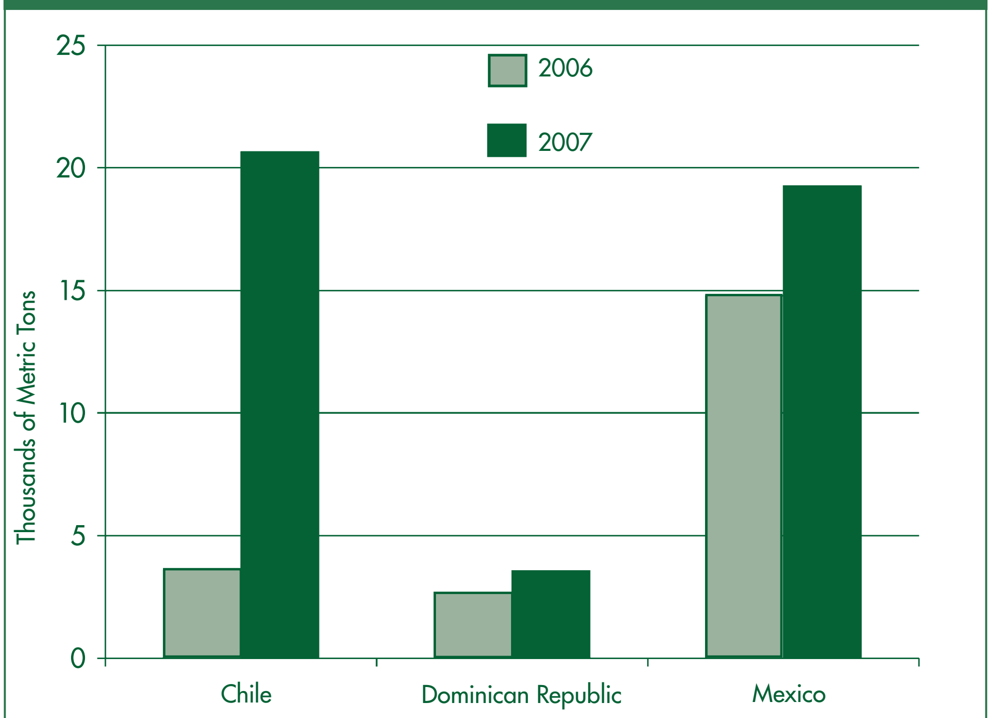
widely by region and, no doubt, by grower within regions. In the Central Valley and desert regions, for example, shippers were reported to have lost 70-80 percent of on-tree lemons, whereas those losses were in the range of 20-30 percent in the Oxnard region. Similarly, some navel orange groves were reported to be unaffected by the freeze, while production from other groves was considered a total loss.

The freeze had a widely varying impact on avocado production as well, based upon estimates compiled by the California Avocado Commission (CAC). Production in Orange County and in the Ventura region is estimated to have been reduced by only five percent, whereas other areas such as Poway in San Diego County, Fillmore in Ventura County, and San Luis Obispo County lost from 50-75 percent of their production.

Although specific crop-loss estimates for vegetables are unavailable at present, it is known that the freeze had a severe impact on desert production of broccoli, cauliflower, celery, and leaf and head lettuce crops. Portions of these crops were destroyed, as, for example, in Oxnard where shippers were forced to disc under much of their celery acreage. Furthermore, parts of the surviving crop suffered a severe degradation in quality, due to blistering, peeling, and reduced shelf life. Iceberg lettuce suffered from abnormally small and compact heads.

In contrast to the annual production cycle for citrus crops, California produces vegetables on a continuous year-round cycle. Thus, losses on the vegetable side were much more transitory than for citrus but still varied widely by commodity. By mid-February some shippers were reporting close to 100 percent harvest of leaf lettuce, with improving quality but still below normal levels. Iceberg lettuce and celery had returned to normal quality by early March. In fact, a market glut for broccoli was reported at the end of February caused by warm desert temperatures increasing supplies that had been stifled by the freeze. For celery, however, a return to normalcy is not expected until mid-March, and shippers were reported to be harvesting in advance of normal timing in order to capture freeze-induced price premiums. This optimism about recovery is tempered, however, by reports that some crops scheduled for spring harvest were damaged in their early production stages, so vegetable consumers may still have not felt the final price and quality impacts of the 2007 freeze.

Figure 1. January Imports of Avocados: 2006 and 2007



Market Adjustments

One reason forecasted impacts from a crop disruption that are made in the immediate aftermath of the event are often erroneous is that commentators fail to consider market adjustments that will occur due to the disruption. One adjustment is prices. If prices are allowed to move freely, they will rise to clear the market at the reduced volume of sales. So shortages, if they materialize at all, will be transitory, and anyone who wants to purchase at the higher prices will be able to do so.

Another adjustment is reallocation of product flows to direct more product to regions affected by the supply disruption. The ability of trade adjustments to ameliorate the impact of the California freeze, however, varied greatly by commodity. For fresh vegetables, the Coachella and Imperial Valleys, along with regions in western

Arizona that were also impacted by the freeze, represent nearly the entire U.S. supply during the winter season. Given that these commodities are highly perishable, imports from remote destinations are not even a consideration.

Avocados represent somewhat of the opposite extreme among the major freeze-impacted commodities. Avocados imported from Chile compete directly with California avocados, and imports from Mexico have been on the rise in recent years due to a loosening of import restrictions. By coincidence, Mexican avocados were allowed into California for the first time on February 1, 2007, just two weeks after the freeze. Before the freeze, imported avocados were expected to account for about 58.5 percent of total 2006-2007 U.S. supplies of 1.03 billion pounds. Now imports are expected to be two-thirds of total U.S. supplies of about 966 million pounds. Figure 1 compares January 2006 and January 2007 avocado imports from Chile, Dominican Republic, and Mexico. Even though the freeze occurred mid-month, we see that imports were dramatically higher in 2007 for all three countries—477 percent higher in the case of Chile. The CAC estimates that 49,256 metric tons of California avocados were lost to the freeze. However, in the month of January alone, 22,476 more metric tons were imported from Chile, Dominican Republic, and Mexico. This means that about 46 percent of the projected California decrement in production was offset by increased imports in the first month alone.

Chilean avocado imports to the United States typically end during February, resuming again in June or July. Although official import figures for February 2007 are unavailable at present, it is known that avocado imports to the United States from Chile continued throughout the month of February in 2007. In fact, it has been reported that California growers temporarily ceased harvesting to let the Chilean fruit clear the market. The Chilean avocados, however, were of considerably lower quality than avocados from Mexico or California. Reflecting both their superior quality and the waning supplies from Chile, California Hass avocado prices have increased steadily in the past month, from $15.67 per lug in mid-February to $21.54 as of March 10. Due to the moderating influence of increased imports, the price impacts of the freeze for avocados are much less dramatic than witnessed for crops without a significant trade component, as the next section demonstrates.

Table 3. Grower Prices for California Citrus[1]

Commodity	January Price/Box		February Price/Box	
	2006	2007	2006	2007[2]
Grapefruit	13.93	15.46	13.33	15.36
Lemons	15.19	21.73	15.59	43.53
Navel Oranges	12.12	14.89	12.42	27.19
Tangerines	22.06	23.76	19.86	24.76

[1] Price reported is packinghouse door fresh price

[2] Preliminary figures

Source: Various issues of "Agricultural Prices," Agricultural Statistics Board, NASS, USDA

Price Impacts

Grower-shipper prices for most freeze-impacted commodities rose dramatically in the aftermath of the frost, mitigating the revenue losses due to reduced production and, no doubt, causing windfall profits for lucky or well-prepared growers whose crops escaped largely unscathed from the freeze. Table 3 provides average grower-shipper price information for California citrus for 2006 and 2007 for January and February, while Table 4 provides similar information for California fresh vegetables.

Table 3 demonstrates that price increases for January 2007 were moderate relative to 2006. There are two reasons—first, the freeze hit the state mid-month, and, second, sales in the post-freeze period were initially from stocks that had been harvested before the freeze, meaning that the market disruption was initially small. Much more pronounced price effects are apparent for February, based upon preliminary data. The per box price for navel oranges rose from $14.89 in January 2007 to $27.19 in February, an 82.6 percent increase. February 2007 navel prices were 119 percent higher than in February 2006. Lemon prices tell a similar story. Price per box doubled from January to February of this year, and February 2007 prices were 179.2 percent higher than a year ago. Notably, price effects were much more moderate for grapefruit and tangerines, quite simply because California is a relatively minor producer of both crops. The supply disruption for these products, although of a similar percentage magnitude in California to the disruption for oranges and lemons, was much smaller on a national scale. In contrast, California annually supplies between 80-90 percent of domestically grown lemons and nearly all of the navel oranges grown for fresh consumption, so in a very real sense the California supply is the U.S. supply for these products.

Consider now the contrasting story for fresh vegetables told in Table 4. Because most of the freeze-impacted vegetables are highly perishable and cannot be stored, the immediate price impact was pronounced. Prices more than doubled for broccoli, lettuce, and onions in January 2007 compared to January 2006, and the price of celery more than tripled. By February, however, supplies and prices had stabilized for broccoli, cauliflower, and lettuce,

Table 4. Grower Prices for Fresh Vegetables

Commodity	January Price/cwt.		February Price/cwt.	
	2006	2007	2006	2007
Broccoli	32.50	70.00	23.80	23.90
Cauliflower	33.10	46.20	26.40	24.40
Celery	9.64	33.90	10.80	58.70
Lettuce	10.50	21.00	12.00	16.60
Onions	11.70	26.50	8.04	25.60

Source: Various issues of "Agricultural Prices," Agricultural Statistics Board, NASS, USDA
[2] Preliminary figures

with 2007 prices varying little from those in 2006. Celery and onion production, however, recovered much less quickly. Celery prices increased to $58.70/cwt. in February 2007, five times the level from the previous year, while onion prices were fourfold higher. These average prices mask considerable price heterogeneity for fresh vegetables during these months, as a consequence of the freeze and the adverse impacts it had on produce quality.

Analysts studying the impacts of the freeze on producers make a considerable error if they fail to consider the price impacts caused by reduced supplies. Economists measure the impact of supply adjustments on price in terms of the price flexibility of demand. (The price flexibility is the inverse of the better-known price elasticity of demand.) We say that price is flexible (demand is inelastic) if a given percentage supply reduction causes a larger percentage price increase. For California commodities with inelastic demands or flexible prices, this means that sales revenues actually increase as a consequence of the freeze, meaning that producers as a group benefit from the supply disruption.

The elasticity of demand facing California growers depends upon the nature of the commodity being produced, including consumer loyalty, the extent of substitutes available, and the magnitude of competing supplies from elsewhere in the United States or from imports. Commodities that are considered essential in diets and face little competition from other goods will have inelastic demands (flexible prices). Fresh vegetables represent this situation. Most consumers consider them to be essential and, as noted, California and western Arizona face little competition during the winter from outside competitors. One recent estimate of the price flexibility of demand for iceberg lettuce is -2.3, meaning that a 10 percent supply reduction would cause a 23 percent increase in price. Although we do not know the precise reductions in supply for the freeze-impacted vegetables, we see the evidence of the high flexibility of price for these commodities in terms of the sharply higher prices summarized in Table 4. The magnitude of the price increases that resulted as markets adjusted to the supply shock suggests that the adverse impact on growers was much less than predicted initially. In fact, many growers and some industries, on average, benefited from the freeze.

One statistical estimate is that the price flexibility for fresh navel oranges is 1.27. The evidence for navel oranges and lemons in the aftermath of the freeze is consistent with inelastic demands and flexible prices. Prices increased on average over January and February at a percentage rate well in excess of the percentage decrease in production caused by the freeze. Of course, these products will continue to be marketed through the spring, so the complete story on the price effect is not yet fully known.

A conclusion that producers for some commodities benefited on average from the freeze does not obviate the fact that many growers were harmed by the freeze or suggest that disaster relief is not justified. Indeed, an important lesson from the freeze is that the impacts in terms of crop loss vary widely across growers and regions, but the price effects are mostly uniform, except for differentials due to quality. Thus, it is easy for winners and losers to emerge from a major crop disruption. Additional losses to growers that are less easily quantified include long-term damage to trees in the case of citrus and avocados. Low quality may also have long-term repercussions for an industry if it causes consumers to lose confidence in the product and reduce demand even after quality has returned to pre-freeze levels.

A final point to note relative to the overall impact of the freeze on California agriculture is the emerging evidence that production of several commodities may actually have benefited from the freeze. They include cherries and other stone fruits, tree nuts, and pears, all of which benefit from sub-freezing temperatures during their dormant state, and strawberries, whose root systems will have been strengthened by the frost.

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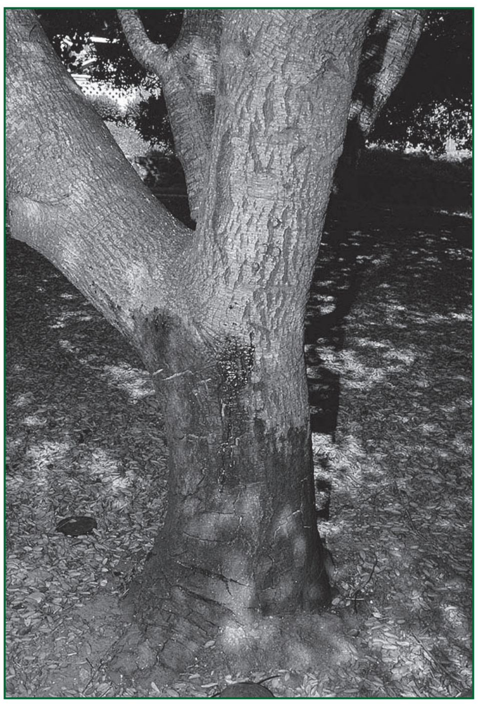
Estimating the Costs of Sudden Oak Death: Results of a Survey of California Nurseries

Jesse Tack and Alix Peterson Zwane

Unique nursery-level survey data are used to quantify pest management costs for California firms impacted by *Phytophthora ramorum* (Sudden Oak Death). We find that nurseries have not shifted production away from host plants, but rather are incurring additional costs to limit their exposure. Despite widespread media attention, estimated management costs have actually been quite low—constituting less than than three percent of annual production expenses.



Sudden Oak Death (SOD) forest disease, has led to the death of tens of thousands of oak trees in California and Oregon. The environmental impacts of SOD may be profound because of the critical role that oaks play in many coastal ecosystems.

Photo courtesy of UC Regents

Since 1995 an emergent fungus-like pathogen *Phytophthora ramorum*, the causal agent of the Sudden Oak Death (SOD) forest disease, has led to the death of tens of thousands of oak trees in California and Oregon (California Oak Mortality Task Force, http://nature.berkeley.edu/comtf). The environmental impacts of SOD may be profound because of the critical role that oaks play in many coastal ecosystems. However, control of *P. ramorum* in natural environments remains elusive. As a result, management costs in the wild, in the areas of tree removal, green-waste disposal, and fire-risk management, are ongoing and often difficult to empirically evaluate.

Recent publicity and regulatory policy have increasingly focused on management challenges that *P. ramorum* represents for the nursery industry. The pathogen can be spread naturally via rain-splash or wind-driven rain, and artificially via shipment of popular ornamental host plants such as rhododendron, camellia, and viburnum. Nursery shipping channels are perhaps the most likely means by which SOD could spread to areas outside of the western United States. Consequently, efforts to prevent the artificial spread are imposing new expenses on a high-value industry in a state where agricultural costs of production are already high.

To date, import restrictions on California nursery products have been avoided through the use of California Department of Food and Agriculture (CDFA)-endorsed SOD-compliance agreements, which legally obligate firms to maintain detailed tracking records and submit to frequent on-site inspection. In return, the agreement certifies the sale of host product that: (i) is produced within a quarantined county (California counties that are under quarantine for SOD: Humboldt, Mendocino, Lake, Sonoma, Napa, Solano, Marin, Contra Costa, Alameda, San Francisco, San Mateo, Santa Clara, Santa Cruz, and Monterey) and transported/sold outside of a quarantined county, or (ii) is produced anywhere in California and transported/sold outside of the state.

At the nursery-level, a SOD infestation can have disastrous short- and long-run implications for financial viability. In response to the 2004 detection of *P. ramorum* at wholesale nurseries in Southern California, over one million nursery plants were destroyed and nursery imports from California were halted by several states. At the time, revenue losses due to extended import restrictions for California producers were estimated to be $100 million. However, costs due to ongoing management and regulatory compliance efforts, as distinct from shocks associated with import restrictions (which were quickly lifted), have not been quantified.

In 2005 we collected original survey data to obtain the first quantitative estimates of the ongoing management costs that SOD-control regulation imposes on California nurseries. Our unique survey data include relevant nursery-level measures that were previously unavailable, and permit acute identification of SOD-control regulatory effects. Behavioral signals derived solely from Agricultural Census data are likely to be overly noisy because there is no way to separate SOD-host producers from non-producers. Thus, our analysis provides an accurate measure of the nursery-level burden imposed by the emergence of *P. ramorum*, a crucial component of the total social costs of SOD, and will help policy

Table 1: Reported Changes for the Feasible Set of Pest Management Actions: Results from a Survey of California Wholesale Nurseries, July 2004 to January 2005

Activity	Percent of all nurseries that reported changes as a result of SOD	Percent increase in average cost of activity
Inventory management	63	10
Fungicide use	40	16
Irrigation or water treatment	7	3
Treatment of cut greens	3	3
Soil management	13	3
Green waste disposal	13	34
Insurance	0	--
Percent of acres devoted to host product	0	--

makers determine appropriate research/prevention investments to combat the (perhaps) more significant costs associated with the artificial spread of *P. ramorum* to areas outside of the current zones of infestation.

In contrast to what may be expected from published reports, our analysis suggests that aggregate management costs, exclusive of those incurred due to infestation, have actually been low and are estimated to be less than three percent of annual production expenses. Thus, while the effects of *P. ramorum* on California's environment may be profound, private costs to the nursery industry so far have been limited.

Original Survey of Nursery Firms

We developed a survey instrument using insights gained from several meetings with nursery industry professionals to collect nursery-level data for our analysis. These professionals included CDFA scientists, nursery-sector lobbyists, University of California Cooperative Extension Specialists, and California nurserymen from several different types of nurseries. The survey questions included topical nursery characteristics (e.g., "how many acres are devoted to growing nursery products/host products?") and cost structure (e.g., "has there been an increase in the cost of your fungicide program specifically due to SOD?"). However, the survey did not request information on actual costs or profit levels, due to concerns about non-response. The survey instrument is available from the authors upon request.

A complete list of California producers of host product is not available, so we identified potential survey participants as licensed nursery wholesalers that produce coniferous evergreens, broad leaved evergreens, deciduous shade trees, deciduous shrubs, or rose plants. All host plants fall into one of these categories, but there are likely firms that produce these categories of products but not hosts. Unfortunately, we cannot identify these producers. We further restricted this sample to nurseries that are strictly wholesalers and operate on at least five acres of land. The CDFA's Plant Health and Pest Prevention Services online directory of California licensed nurserymen provided detailed location information for 255 nurseries that fit our search criteria, but not telephone numbers.

To contact nurseries, we compiled an initial list of telephone numbers using the Google search engine, which produced phone numbers for 142 nurseries. An additional 44 telephone numbers were obtained through various other channels, including conversations with nurserymen and nursery-sector lobbyists. In total, we gathered numbers for 186 (of the 255) potential survey participants, and then began contacting them to determine if they produce host product. Ultimately, we spoke with managers at 112 firms, of which 68 produced host product since 2002—the year SOD regulation began. Among these host producers, 45 managers participated in our survey, 30 of whom completed an extended version which identified the feasible set of pest-management activities relating to SOD.

Actual SOD Control Expenditures

Table 1 summarizes responses from the 30 extended surveys and indicates that fungicide and inventory management are the most likely responses to SOD control. Few nurseries are investing in improved irrigation/water treatment, treatment of cut greens, soil management, or green waste disposal. They do not report expanding insurance coverage either. A few firms do report high green waste disposal costs, but these are likely a consequence of infestation and associated stock destruction, rather than *ex ante* investments.

An important insight from Table 1 is that nurseries in our sample have not significantly shifted production away from host plants, which implies that pest-management investments are the primary means of mitigating SOD exposure. This finding is not an artifact of our sampling methodology; we over-sampled large nurseries and nurseries that have entered into a SOD-compliance agreement, which are the types of nurseries that are most likely aware of the impact that continued host production will have on future profit streams. In our full sample of 45 nurseries, 22 percent of the nurseries are located in a quarantined county and 58 percent have signed a SOD-compliance agreement. While Table 1 shows that almost 40 percent of firms report no changes in inventory management costs and 60 percent of firms report no changes in fungicide use, the standard deviation for both variables is about double the mean value, so investment levels are high for some nurseries.

Discussion

The survey data indicate that nurseries have not shifted production away from host product in order to limit their exposure to a *P. ramorum* infestation. Rather, they are actively investing in fungicide and inventory management by monitoring host plants and surrounding areas for symptoms of SOD, as well as maintaining accurate shipping documentation for the purpose of effective tracebacks and traceforwards (Table 1). These additional expenditures translate into modestly increased production expenses at the nursery level on average.

Simple econometric analysis (using techniques to account for the fact that some types of firms may have systematically been included in our sample data) indicates that these additional costs, while relatively small, are not borne equally across nurseries. Not surprisingly, growers of host product are incurring higher fungicide and, especially, inventory management costs. Higher costs are also being incurred by nurseries located in counties where SOD spreads through natural channels as well as via product shipment. In practice this means that the relatively large nurseries in California, which are located outside of the quarantined counties, are incurring disproportionately lower costs.

The estimated increase in ongoing pest-management costs for the average nursery under the current regulatory regime is about $13,500 per year. In the event that all California counties are quarantined ("full-quarantine" regime), the estimated cost increase for the average nursery is $29,500 per year, more than double the current impact. The reason for the large increase across regulatory scenarios is that nurseries in the current quarantined counties are, on average, smaller and have a lower percentage of host product; thus, by moving to the full-quarantine regime, the average nursery located in an infested area is both larger and produces a higher percentage of host product, both of which have a positive effect on cost increases.

Total impact for the average nursery under the current regulatory regime is quite small compared to annual production expenses. In 2002, the average nursery spent $528,000 in total production expenses (2002 California Census of Agriculture), which implies that total impact under the current regulatory regime is only a 2.6 percent increase in production expenses. Under the full quarantine regime, total impact is only a 5.6 percent increase in production expenses. However, it is important to point out that these cost changes are ongoing at the nursery level, meaning that the new level of cost for each nursery will be sustained indefinitely. Moreover, additional costs would be incurred in the event of an infestation as a result of product destruction and lost sales.

These relatively modest aggregate costs are likely a result of the regulatory regime adopted by the CDFA, which has been effective in preventing import restrictions and has passed a key cost of SOD monitoring on to taxpayers. Critically, the costs of testing for SOD and maintaining certification for California export sales, including both labor and laboratory analysis, are borne by the CDFA.

Conclusion

Nurseries are actively investing in inventory management and fungicide in order to limit their exposure to SOD. Our analysis shows that few nurseries are actively investing in other pest-management actions, and that nurseries have not significantly shifted production away from host plants. This implies that nurseries view the investment in pest-management actions as the primary means of combating a *P. ramorum* infestation at this time.

We use original survey data to identify actions that nurseries are taking in response to SOD and provide the first quantitative estimates of the costs that SOD-control regulation imposes on the California nursery sector. Our analysis suggests that additional costs are not borne equally; rather, costs are higher for nurseries in quarantined areas. This suggests that the largest industry players are not bearing proportional cost increases since they are not located in the currently designated infestation zones. In addition, we find that, despite widespread media speculation, estimated costs are quite low as they represent less than three percent of annual production expenses under the current regulatory regime.

In conclusion, while the effects of *P. ramorum* on California's environment are likely profound, private costs to the nursery industry have been limited. This finding is largely a result of the current policy regime, as state regulators are actively funding a portion of pest-management expenses (on-site testing) and have designed a credible certification scheme which effectively limits the probability of market closure.

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For more information, the authors recommend:

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