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Invasive Species, Border Enforcement, and Firm Behavior

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Globalization has led to a growing volume of goods moving among nations and the introduction of invasive organisms. Port inspection is a major form of protection against invasive species. We find that their effectiveness will increase through policies that reduce the cost and increase the effectiveness of pretreatment of products before they enter the ports.

Also in this issue

Globalization, and its accompanying increase in trade, has not been without complications. Agricultural producers in the United States claim that increases in imports under trade agreements such as the North American Free Trade Agreement (NAFTA) and the World Trade organization (WTO), have been the main cause of an increase in invasive species introductions. They argue that USDA's APHIS (Animal and Plant Health Inspection Service) and other responsible government agencies are not adequately addressing these risks. Industry groups have also pushed for more stringent policies concerning invasive species, arguing that the United States' reputation as an exporting country needs to be protected. In contrast, foreign agricultural producers and importers argue that U.S. producers overstate their vulnerability to pests with the aim of imposing more stringent sanitary and phytosanitary measures that effectively serve as protectionist barriers to trade. As trade volumes increase, these issues become more contentious.

The most obvious policy solution for addressing cross-border risk—increasing investment in border control measures to encourage international firms' risk-controlling behavior—is not as straightforward as it may seem. Funding is limited and border control efforts are highly complex, especially given institutional changes such as the transition of agricultural inspections from APHIS to the Department of Homeland Security, Customs and Border Protection in 2003. Increased border measures can cause indirect adverse effects, such as significant delays at the border and significant losses if products reach their final destination damaged or late. Increased border enforcement also causes unintended consequences by increasing firms' incentives for avoiding these measures.

Policymakers hope that border protection measures have a deterrence effect, that firms increase due care with respect to pest control. However, agricultural inspection officers indicate that avoidance and evasive behavior on the part of importers is a significant and complex problem. For example, importers of high-risk goods (e.g., prohibited goods or goods contaminated with pests) may attempt to circumvent enforcement efforts. Some may take overt action to avoid detection, such as falsifying cargo manifests, or placing contaminated goods in hard-to-reach locations or hidden compartments. A more subtle approach to avoid detection is "port shopping," the practice of directing shipments to ports where importers believe products will undergo less scrutiny based on the enforcement reputation of inspectors at different ports. Importers port shop in order to avoid inspectors who are considered especially effective or well informed concerning companies with poor reputations. Alternatively, firms may respond

Port inspections are essential to reducing or eliminating invasive species risk.

to increased enforcement with changes in import supply. That is, they may decrease the amount of goods they attempt to import, or import a different mix of goods. Even those importers who have no doubts about the quality of their goods, and have applied appropriate pest-control efforts, have incentives to avoid the inconvenience and delay associated with inspections.

Introductions of invasive species are low-probability, high-consequence events. Thus, collecting data on invasive species and trade, such as how many infected shipments pass through borders undetected or the probability of invasions resulting from these undetected shipments, is a challenge. Moreover, firm behavior, such as placing high-risk goods in hard-to-inspect locations or switching ports of entry, is difficult to quantify. This may explain in part the lack of quantitative research on border enforcement with regard to invasive species management.

To address this need, we undertook a multipart research project, funded through USDA's Program of Research on the Economics of Invasive Species (PREISM), that resulted in the development of an agent-based model of border enforcement. Agent-based modeling (ABM) or agent-based computational economics, a growing area of research, allows heterogeneous agents to interact, learn, and respond within a defined system, and can predict outcomes that arise from the selection of particular enforcement instruments. These techniques are only just beginning to be applied in agricultural and environmental economics research, and have never been applied to questions of importer and inspector behavior for border enforcement and invasive species management.

We first developed a theoretical model to analyze firm response to border enforcement and a spatially explicit damage function to estimate the impacts of invasive species introductions. We then constructed an ABM framework incorporating the spatially explicit damage function, and applied the framework to a representative commodity (broccoli), invasive species (crucifer flea beetle), ports of entry (Calexico and Otay Mesa, Mexico /U.S. land ports, respectively), and vulnerable location (California).

We used this framework to evaluate the impacts of port-specific and importer-specific enforcement regimes for a given agricultural commodity that presents invasive species risk. The ultimate objective was to improve the allocation of scarce enforcement resources and to provide an adaptable tool that can be used by policymakers to answer further questions concerning border enforcement and invasive species risk.

The theoretical model, which provided the underlying structure for the ABM, considered two enforcement regimes (destruction versus treatment of contaminated goods) and evaluated both intended and unintended firm response, as well as pest population effects. The results indicated that increased enforcement (in the form of higher inspection intensity) will not necessarily result in reduced pest risk. Importers may respond to increased inspection intensity by lowering shipment amounts and increasing point-of-origin treatment (i.e., care), but under certain conditions they may actually respond by decreasing care in order to lower the cost of shipment. Similarly, these same conditions also dictate whether or not firms will increase or decrease the level of care as pest populations increase at the point of shipment. In response to environmental conditions such as increased pest populations, firms may reduce output and increase due care, so a simultaneous increase in enforcement may not be necessary and, in fact, may be suboptimal. This is a critical consideration for policies that prioritize inspections on the basis of changes in the level of pests in specific exporting countries.

This model was extended to a two-port case. The results showed that a change in port-specific revenues or costs will make firms more likely to change their port choice. Less obvious were the results that a change in initial pest populations or a uniform change in enforcement may also bring about a shift in port choice. Of course, whether these changes are expected to be long- or short-term, the cost to firms to shift output between ports, along with firm type, will determine whether a change in port choice occurs.

We selected broccoli as the specific commodity pathway modeled in the project based on the data from the Work Accomplishment Data System collected by the USDA. The vast majority of the U.S. broccoli crops is grown in California—128,500 acres in 2006. The average value of these crops was approximately $4,700/acre. Broccoli exports in 2002 were valued at over $116.5 million, while imports were valued at $28.1 million, 89.4% of them from Mexico. In the upcoming years, trade volumes of broccoli may increase due to changes in broccoli tariffs under NAFTA.

The invasive species of concern for broccoli in our example is the crucifer flea beetle (*Phyllotreta cruciferae*) because of its potential as one of the most damaging pests for broccoli in California. Broccoli is shipped from Mexico to California via land ports (Calexico and Otay Mesa), airports (San Diego and Los Angeles), and marine ports (Long Beach). The analysis focused on shipments of broccoli from Mexico to California via two ports—Calexico and Otay Mesa, located in San Diego County. Calexico East handles both commercial and personal border crossings and averaged approximately 289,000 trucks per year between 2001 and 2006. Otay Mesa is the largest commercial crossing along the California/Mexico border and averaged approximately 724,000 trucks per year in the same time frame.

We developed a spatial damage function that estimated the probability of pest establishment, using a degree-day model to predict the occurrence and spread of the crucifer flea beetle in California, and the resulting damage to broccoli crops. Results from this analysis showed that the probability of emergence and spread of the crucifer flea beetle in California was higher from January through June, with the highest probabilities in January, February, and March. Examples of these probability maps are shown in Figures 1 and 2. The model assumes a constant level for the broccoli crop throughout the year. It should be noted that estimates for broccoli crop damage were based only on the influence of weather and climate as predictor variables.

The ABM was created and run in NetLogo, a free software package. A map of California broccoli crops was layered with the establishment probability maps, and additional spatial information on the location of ports of entry and major highways and transportation routes. Through the actions of the importers, the ABM allows the

Figure 1. Probability of Adult Flea Beetle Emergence: January 15–31

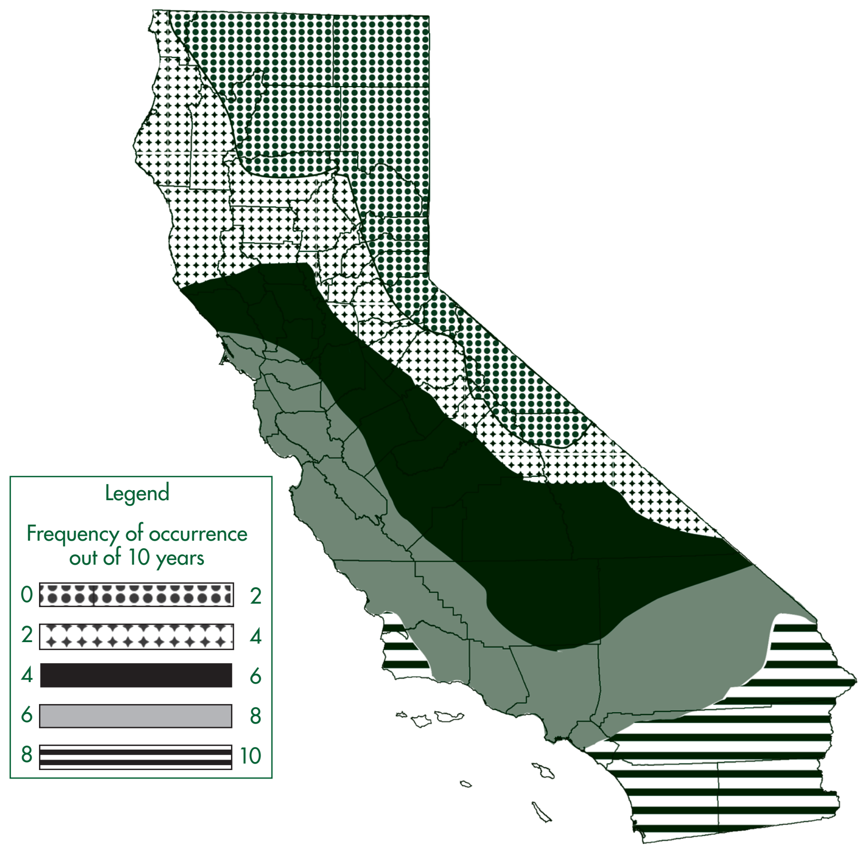
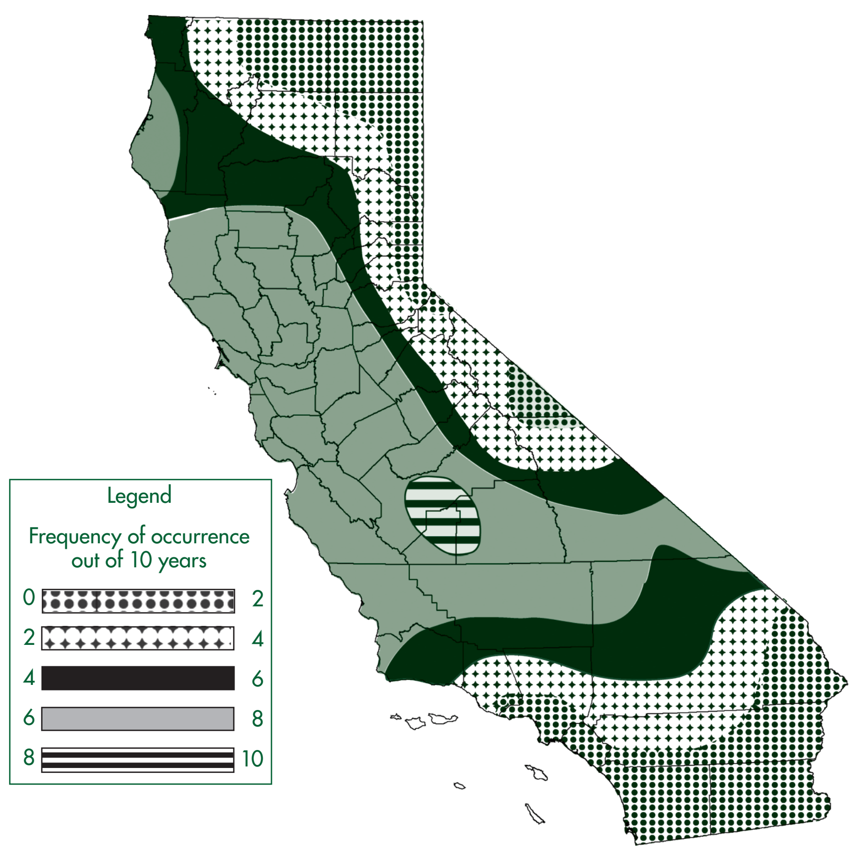


Figure 2. Probability of Adult Flea Beetle Emergence: February 15–28



crucifer flea beetles to be introduced and demonstrates the effects of border enforcement policies on broccoli crops. A key aspect of the ABM methodology is the capability to analyze the behavior of heterogeneous actors. In this model, three types of importers were created that differ in terms of infection rates (high, medium, and low) and cost of transportation to the port.

The model incorporates inspection rates for each port and each importer (to capture the effects of potential repeat offenders), and the success rate of inspection (i.e., finding an infected shipment when one is present), not only for each port and importer but also for each potential level of pretreatment.

The ABM analysis generated several policy-relevant findings. In addition to increasing pretreatment efforts in response to increased inspection rates, firms may switch away from one port to another with lower inspection rates.

While the model showed the expected reduction in crop damages as inspection rates were increased at a specific port, it also showed the conditions under which marginal damage reduction was flat versus steep. More dramatic damage reduction occurred when inspection rates at both ports were relatively high. The implications are that, under certain conditions, policymakers should not be focused on consistency across ports but rather on ensuring inspection rates at other ports are high. Alternatively, if inspection rates across ports are relatively low, unless inspection rates can be raised significantly and inexpensively at all ports, policymakers should not invest in increasing inspection rates at just one or a few ports.

This analysis highlights the policy importance of distinguishing between inspection rates versus the rates at which these inspections are successful. The results show that crop damages may increase as the base rate of inspection increases, given low inspection and inspection success rates for certain importers. Moreover, increasing enforcement efforts may not necessarily reduce invasive species risk.

Port inspections are essential to reducing or eliminating invasive species risk. Without inspections or the perceptions of inspections, importers lose the incentive to ensure that their shipments are pest-free. Importers will not invest money in pretreatment efforts if there are no potential benefits (such as saving money on violation fines). That said, given the model's findings that a dramatic decrease in damage follows a decrease in cost of pretreatment, regulators may more successfully reduce invasive species risk by targeting pretreatment costs and effectiveness rather than by expending more effort at the ports. While it is important to make sure that our trading partners are meeting our standards at the border, it may be even more important to help them find better—and cheaper—ways to do so.

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Ameden, H.A., P. Boxall, S.B. Cash, and D.A. Vickers. 2009. An Agent-Based Model of Border Enforcement for Invasive Species Management. *Canadian Journal of Agricultural Economics* 57:481-496.

Ameden, H.A., S.B. Cash, and D. Zilberman. 2007. Border Enforcement and Firm Response in the Management of Invasive Species. *Journal of Agricultural and Applied Economics* 39(October):35-46.

Loomis, J., C. Bond, and D. Harpman. 2009. The Potential of Agent-Based Modelling for Performing Economic Analysis of Adaptive Natural Resource Management. *Journal of Natural Resources Policy Research* 1(1):35-48.

Nolan, J., D. Parker, G.C. van Kooten, and T. Berger. 2009. An Overview of Computational Modeling in Agricultural and Resource Economics. *Canadian Journal of Agricultural Economics* 57:417-429.

Spotted Wing Drosophila: Potential Economic Impact of a Newly Established Pest

Mark P. Bolda, Rachael E. Goodhue, and Frank G. Zalom

While significant gaps and uncertainties exist in scientific knowledge regarding spotted wing drosphila, it has the potential to cause substantial economic damage, particularly for specific crops and regions in California.

Spotted Wing Drosophila (SWD). Very little is known about the potential for crop damage due to SWD, but certain crops and regions may incur economic damage as a result of the establishment of this invasive species.

Photo by Martin Hauser, courtesy of University of California Statewide IPM Program

The spotted wing drosophila (*Drosophila suzukii*), a native of Southeast Asia, is a pest of berry and stone fruits. Its first detected North American invasion was in August 2008 in Santa Cruz County, California on strawberries and caneberries. In May 2009, additional infestations were detected in cherry orchards along California's Central Coast, in the Santa Clara Valley, and from Yolo to Stanislaus Counties.

Further trapping and identification efforts confirmed the presence of spotted wing drosophila (SWD) over a wide geographic range, extending the entire length of California's coastal counties north into British Columbia. SWD has been found on a variety of commercial and backyard host crops in these areas, including apples, blackberries, blueberries, cherries, grapes, nectarines, peaches, pears, plums, raspberries, and strawberries. The potential for its further expansion to additional soft-skinned fruit and vegetable hosts is unknown. SWD prefers a moderate climate such as that along the Pacific Coast, but it has been reported in relatively cold areas of northern Japan.

Although it is an invasive pest, by the time of its detection SWD had established itself to such an extent that eradication was deemed impossible by the California Department of Food and Agriculture. Relatively little is known about the biology of SWD, including its ability to overwinter, its seasonal cycle, or the determinants of its seasonal abundance. Similarly, little is known about potential biological and chemical controls for SWD, although a natural enemy of related non-pest drosophila species has been observed parasitizing SWD in Oregon. Given the extent of the invasion and this limited knowledge, there is the potential for SWD to create substantial economic damage, at least in the short term.

We provide preliminary estimates of the value of production of selected host crops that could be lost due to SWD infestations. Rather than predicting actual economic damage due to SWD, our estimates are intended to illustrate the *potential scope* of economic damages. The significant gaps in scientific knowledge regarding the biology and control of SWD, coupled with the substantial degree of uncertainty regarding the applicability of knowledge obtained elsewhere to the West Coast, prohibit definitive economic analysis.

SWD infestations can reduce marketable yields greatly. Yield loss estimates from 2009 observations range from negligible to 80%, depending on location and crop. Unlike related common vinegar fly species, which prefer overripe fruit, SWD prefers to lay its eggs in fresh soft fruit underneath the skin, rendering the fruit unmarketable. The larvae hatch, and then burrow inside the fruit to continue their development. Thus, in the earliest stage of infestation the only visible sign of damage to fruit is the oviposition sting, even when larvae have hatched inside the fruit.

Economic Impact on U.S. Production of Selected Host Crops

SWD infestations have the potential to affect significant shares of total U.S. production of certain host crops. The majority of U.S. small fruits production occurs in the Pacific Coast states. In

Table 1. Revenue Losses Due to SWD: 20% Yield Loss, 2008 Value of Production

	California	Oregon	Washington	Three-state Total
Strawberries				
Total farmgate value ($Million)	1,544.7	16.8	10.1	1,571.5
Share of U.S. production (%)	82	1	1	83
Total losses ($Million)	308.9	3.4	2.0	314.3
Blueberries (cultivated)				
Total farmgate value ($Million)	49.1	49.4	43.4	141.9
Share of U.S. production (%)	9	9	8	26
Total losses ($Million)	9.8	9.9	8.7	28.4
Raspberries and Blackberries				
Total farmgate value ($Million)	179.5	41.7	92.1	313.3
Share of U.S. production (%)	57	13	29	100
Total losses ($Million)	35.9	8.3	18.4	62.7
Cherries				
Total farmgate value ($Million)	194.5	58.7	297.1	550.3
Share of U.S. production (%)	30	9	45	84
Total losses ($Million)	$38.3	$9.9	$57.8	$105.9
ALL CROPS				
Total farmgate value ($Million)	1,967.9	166.5	442.6	2,577.0
Share of U.S. production (%)	58	5	13	76
Total losses ($Million)	393.0	31.4	86.9	511.3

Source: Authors' calculations based on data from the National Agricultural Statistics Service (NASS), 2009.

2008, California, Oregon, and Washington accounted for all commercial U.S. raspberry and blackberry production, 84% of the value of commercial cherry production, 83% of the value of strawberry production, and 26% of the value of blueberry production. For these four crops as a group, 76% of the total value of U.S. commercial production is grown in these three states, or $2.6 billion. Table 1 reports the value of production by state for each crop, and the share of each state's production in the national total.

The single estimate of a 20% yield loss does not reflect all information collected to date, although it serves as an average benchmark loss across the range of crops and production regions. While specific yield losses have not been observed for all crops in all regions, yield losses have been recorded for specific crop-region pairs. Of course, over time damage estimates may change, as additional infestations are documented. In addition, the development of effective control measures may mitigate yield losses relative to these early observations. On the other hand, as SWD becomes established at greater population densities, damage rates could increase. Table 2 reports estimated economic losses based on maximum reported yield losses: 40% for blueberries, 50% for blackberries and raspberries, and 33% for cherries. Losses for strawberries vary by location and end use.

California strawberries present an interesting case. To date, relatively little economic damage has been observed on strawberries, which is thought to be due at least in part to the short time interval between harvests of strawberries for the fresh market in California. Because there is a longer harvest interval for strawberries designated for processing, yield losses may be greater for this segment of the market. Thus, for processing strawberries we assume the yield loss of 20% observed in Oregon strawberries, which have a similar harvest interval.

When we include the upper bounds of the ranges of observed yield losses, economic losses increase substantially for Oregon and Washington, due to increased yield loss estimates for raspberries and blackberries. Losses for Oregon almost double. Losses for Washington increase by 85%. Because these states account for such a large share of U.S. production of these crops, the national impact on the value of production would be substantial. For California, losses decrease by almost 50% due to the relative importance of strawberries in the total value of production of the crops considered.

Economic Impact on Selected Coastal Berry-producing Counties in California

State-level estimates may not represent the importance of the economic impact of SWD for specific regions. Within each state, production of specific host crops may be concentrated regionally; for example, virtually all of California's strawberry and caneberry production is concentrated along the coast between San Diego and Monterey. These regions would bear the losses due to SWD. Tables 3 and 4 examine potential economic losses for three counties along the California coast that account for the vast majority of California's caneberry production and a substantial share of its strawberry production: Santa Cruz, where SWD was first detected, Monterey, and Ventura.

These counties are important to California agriculture. Monterey has the fourth highest value of agricultural production among all California counties, and Ventura ranks tenth. Berry crops are important components of the value of agricultural production in these coastal counties. Strawberries are the single largest crop based on the value of production in Santa Cruz and Ventura Counties, and the second largest in Monterey. Raspberries are the second largest crop in Santa Cruz County and the fifth largest in Ventura County. Berries accounted for 17% of the total value of Monterey County's agricultural production, and just under a third of Ventura County's. Santa Cruz is distinguished from the other coastal counties by its high reliance on berries; 60% of its total value of agricultural production is berry crops. The importance of berries to these counties indicates that regional losses due to SWD damage could be significant.

We focus first on raspberries. Table 3 reports economic losses for a range of potential yield losses due to SWD infestation. As a benchmark, we include a zero percent loss, and extend the range to the maximum observed 50% yield loss. On average, raspberry yield losses to SWD damage in the Central Coast region were about 20% in the 2009 growing season. This average was not realized by every producer; a small share of growers (10%) is estimated to have sustained large losses (70%), a slightly larger share (20%) faced relatively small losses (10%), and a majority of growers (70%) did sustain the average loss of around 20%.

As shown in Table 3, at an average yield loss of 20%, revenue losses in these three counties were $42.9 million. Because raspberries are a particularly important crop for Santa Cruz County, the county's total value of agricultural production would decline by four percent. Because Monterey and Ventura Counties have much higher total values of agricultural production and raspberries are relatively less important, total revenues from agricultural production in Ventura County would decline by only one percent and the change in Monterey County's total agricultural revenues would be negligible.

Table 2. Revenue Losses Due to SWD: Maximum Observed Yield Losses, 2008 Value of Production

	California	Oregon	Washington	Three-state Total
Strawberries				
Total farmgate value ($Million)	1,544.7	16.8	10.1	1,571.5
Share of U.S. production (%)	82	1	1	83
Total losses ($Million)	28.0	3.4	2.0	33.4
Blueberries (cultivated)				
Total farmgate value ($Million)	49.1	49.4	43.4	141.9
Share of U.S. production (%)	9	9	8	26
Total losses ($Million)	19.7	19.7	17.3	56.7
Raspberries and Blackberries				
Total farmgate value ($Million)	179.5	41.7	92.1	313.3
Share of U.S. production (%)	57	13	29	100
Total losses ($Million)	89.8	20.8	46.0	156.6
Cherries				
Total farmgate value ($Million)	194.5	58.7	297.1	550.3
Share of U.S. production (%)	30	9	45	84
Total losses ($Million)	63.2	16.3	95.3	174.8
ALL CROPS				
Total farmgate value ($Million)	1,967.9	166.5	442.6	$2,577.0
Share of U.S. production (%)	58	5	13	76
Total losses ($Million)	200.6	60.2	160.7	421.5

Source: Authors' calculations based on data from NASS, 2009.

Although to date SWD damage has largely not been observed on California strawberries, this situation may change. Higher pest population densities may lead to greater infestations of strawberry fields. In addition, because the SWD is a mobile pest, management decisions and pest populations on nearby fields can influence populations and yield damage in a given field.

As strawberry fields transition into harvesting for processing, SWD could move from the old crop to new strawberry crops in nearby fields, due to overlaps between summer and fall plantings. This could increase yield damage on new fields when the fresh-market harvest begins. Based in part on observed infestations and damage in Oregon strawberries, wet weather also increases yield losses. Strawberry fields near caneberry plantings may also sustain infestations, especially when the caneberry harvest and SWD control are not managed effectively. Due to such considerations, Table 4 presents economic losses for a range of yield losses due to SWD damage in strawberries. The maximum yield loss considered is 20%, the loss observed in Oregon strawberries.

As shown in Table 4, due to the large value of the strawberry crop

Table 3. Revenue Losses due to SWD as a Function of Yield Loss: Raspberries

Yield Loss (%)	Revenue Loss ($Million) Santa Cruz	Monterey	Ventura	Total
10%	10.6	2.4	8.5	21.5
20%	21.2	4.8	16.9	42.9
30%	31.7	7.2	25.4	64.4
40%	42.3	9.6	33.8	85.8
50%	52.9	12.1	42.3	107.3

Source: Authors' calculations based on data from NASS, 2009.

Table 4. Revenue Losses due to SWD as a Function of Yield Loss: Strawberries

Yield Loss	Revenue Loss ($Million)			
(%)	Santa Cruz	Monterey	Ventura	Total
1%	1.6	6.2	3.9	11.7
2%	3.2	12.4	7.9	23.5
5%	8.0	31.0	19.7	58.7
10%	16.0	61.9	39.4	117.3
20%	32.1	123.9	78.7	234.6

Source: Authors' calculations based on data from NASS, 2009.

in these three counties, even a small percentage yield loss can lead to significant revenue reductions.

Caveats

Any economic impact analysis is subject to the uncertainties in underlying scientific analysis. In the case of SWD, because it is a recent invader and the international literature on the species surprisingly limited, the scientific uncertainty is high and further research is required. Here we focused attention on a very limited set of host crops. SWD has been observed on other hosts, and the full potential range of fruit and vegetable hosts is unknown. If a larger number of hosts had been considered, potential economic losses would have been larger.

The estimated yield losses are based on a limited number of field observations to date. Estimates of yield losses, and the factors that influence them, will evolve over time as additional data are collected. Furthermore, realized yield losses will depend on the efficacy of available control methods. As efficacious control methods for various host crops are identified and implemented, realized yield losses will decline, all else equal.

In addition, our analysis computes losses based solely on the value of production for these crops. We do not take into account any changes in price that may result from a reduced supply from the three states considered. Any increase in price due to a reduced supply would offset to some extent the reduction in revenues due to the reduction in the quantity produced. Similarly, we do not consider any changes in consumer welfare that may occur; our analysis is limited solely to the effects on producer revenues.

The net effect of these considerations on our analysis is indeterminate. To the extent that competing domestic and international suppliers can increase production to offset reduced production in California, Oregon, and Washington, prices will not rise, so consumers will be unaffected but producers will face larger revenue losses. If trading partners impose trade restrictions due to SWD infestation, then either growers will no longer have access to those markets or they will have to implement potentially costly phytosanitary practices in order to continue to export to those countries. Finally, while efficacious control methods will reduce realized yield losses, they will also raise production costs to an unknown extent. Nonetheless, in spite of these many considerations, it is apparent that there is substantial potential for certain crops and regions to incur economic damage as a result of the establishment of SWD.

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Bolda, M.P., W.W. Coates, J.A. Grant, F.G. Zalom, R.A. Van Steenwyk, J. Caprile, and M.L. Flint. 2009. Spotted Wing Drosophila, *Drosophila suzukii:* A New Pest in California. Univ. Calif. Statewide IPM Program. www.ipm.ucdavis.edu/EXOTIC/drosophila.html.

Golf Courses in California As Modern Agricultural Enterprises

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Golf courses are producing a "high value agricultural crop" as the economic benefits per acre are higher than for most crops. The consumption activities related to golf generates $1.15 of value added for every dollar of revenue generated in the golf course.

The definition of agriculture changes over time. Agriculture is the cultivation of plants and husbandry of animals, that is, the management of living things and ecosystems to produce goods and services for people. Maintenance of a golf course entails intensive cultivation of turfgrasses and other plants to enable consumers to play and practice golf. Under this, golf course maintenance is part of agriculture and golf courses are types of modern agricultural enterprises. Food, fiber, fodder, and fuel are well-recognized agricultural goods, but fun, or an outdoor venue for it, is not well-recognized as an agricultural service.

At golf course facilities, people also can play other sports, eat or dine, sleep, and participate in other social activities. Thus, facilities with golf courses are multi-output, agriculturally-based recreational businesses that share much in common with other multi-output, agri-tourist businesses: wineries, restaurants operated by farmers, dude ranches, and bed-and-breakfast inns on traditional farms. Golf courses and similar agribusinesses have to be included in policy discussions about resource allocation for agriculture and rural development.

In this article, we present an overview of golf course facilities in California based on relatively new information about water use for conventional agriculture in the state and recently revised results of surveys done in 2001 and 2002. We first describe the distribution of types of golf course facilities. Second, we discuss the chief output of a golf course facility and present information about revenues that facilities earn for supplying landscapes to play and practice golf. Third, we assess input use and compare revenues generated per acre of land and acre-foot of water on golf courses to other agricultural industries. We conclude by underscoring the importance of a broad, inclusive view of agriculture.

Golf Course Facilities in California

The golf course industry caters to many types of golfers whose income and patterns of play vary. The industry is a source of export revenue for the state because it attracts tourists but also provides recreation to local citizens. A diversity of golf course facilities reflects the diversity of market segments served by the industry. California had 891 facilities with golf courses that were open for play as of January 1, 2001. In terms of the number and length of holes, 55.4% of all facilities had one 18-hole regulation course. The second, third, and fourth most prevalent types had 9 holes that constituted a regulation course (11.1 %), an executive course (8.5%), and a par-3 course (6.1%). Facilities with two 18-hole regulation courses and one 27-hole regulation course accounted for 5.0% and 3.6% of the total, respectively. Facilities with one 18-hole executive course and one 18-hole par-3 course represented 4.4% and 1.5% of all facilities, respectively.

In terms of access to courses and ownership, public facilities accounted for 62% of all of California's facilities in 2000. In particular, facilities with nothing but daily-fee courses and those with only municipal courses represented 41% and 21% of all facilities, respectively. Clubs with private golf courses accounted for 31% of all facilities: 20% were equity clubs and 11% were non-equity clubs. Facilities with only resort courses accounted for 6% of the total. The remaining five facilities had combinations of private non-equity and resort courses, daily-fee and resort courses, and private non-equity and daily-fee courses.

The distribution is even more complex if one classifies golf course facilities jointly by the number of holes, the length of the course, and the access and ownership. In this case, the most common type of facility had one 18-hole regulation, private course; 22.4% were this type. The second most common type, 19.4% of all facilities, had one 18-hole regulation, daily-fee course. The third most common type, 10.9% of all facilities, had one 18-hole regulation municipal course. Facilities with one 9-hole regulation, daily fee course accounted for 6.7% of all and were the fourth most common. The fifth most common, 4.7% of facilities, had one 9-hole executive, daily-fee course.

Following procedures of Dillman, we conducted a survey of the state's 891 golf-course facilities in 2001 and 2002. The survey response was 21%; managers or superintendents of 187 facilities returned surveys with usable answers to our questions. Private, municipal, daily-fee, and resort facilities with an 18-hole regulation course accounted for 26.2%, 18.2%, 15.0%, and 1.6% of respondents, respectively. Non-resort facilities with a 9-hole non-regulation course and those with a 9-hole regulation course represented 10.7% and 9.6% of respondents. Non-resort facilities with 36 holes, 27 holes, and 18 non-regulation holes accounted for 8.0%, 5.3%, and 4.3% of respondents, respectively. The response rate to a similar survey was 17% in Florida.

Revenues from Golf Facilities

People spent $4.414 billion in total at California's golf course facilities in 2000. The most important product of a golf-course facility is a round of golf. Golfers in 2000 played 41.1 million 18-hole-equivalent paid rounds in California. They paid $1.668 billion in golf membership dues, green fees, golf car fees, advanced booking fees, tournament fees, and miscellaneous charges to use California's golf courses in 2000. Payments for rent of golf cars, pull carts, and caddy services, as well as payments of trail fees for annual use of personal golf carts, were $235 million of this total. In addition to $1.668 billion, golfers also paid $76.9 million in ball-bucket charges and fees to practice at on-site driving ranges. In total, people paid $1.745 billion in 2000 to play and practice golf at the state's golf course facilities. This amount represented only 40% of the total receipts of golf course facilities in the state.

Other expenditures at golf course facilities included $980 million for food and beverages, $825 million for lodging, $252 million for merchandise from on-site golf shops, and $85.0 million for clubhouse rental.

Direct, indirect, and induced sales generated $4.631 billion in personal income and $1.396 billion in taxes in 2000. Direct sales supported 63,055 jobs and, through indirect and induced sales impacts, an additional 40,405 jobs. The total value added by the facilities was $5.081 billion and accounted for 0.39% of the California's gross state product in 2000.

Golf Course Maintenance as Farm Work

Golf course superintendents and their staff manage turfgrasses, trees, and other plants in precise configurations to maintain courses, practice greens, and driving ranges. These landscapes provide venues to play and practice golf. Superintendents and their staff also manage water bodies, clubhouse grounds, and other landscapes around the facility to enhance golfing, dining, lodging, shopping for golf-related merchandise, and other recreational activities. They spent a total of $821.5 million in 2000 for agricultural management of golf courses, driving ranges, and other landscapes at the facilities in California.

The largest part of this expense was $686.6 million to maintain and improve golf courses and other landscapes around the facilities. This estimate covers wages and salaries, purchases of plant materials, pest management costs, fertilizer expenses, water charges, minor repairs of equipment, and any other expense for the care of trees, shrubs, grass, other plants, and water features on grounds around the facility. Capital expenditures on major equipment for golf course maintenance, installation of new irrigation systems, renovation of a significant planted area, and other landscape improvements constituted the remainder of the $821.5 million.

Maintenance and improvement of the landscapes at a golf course facility entail numerous jobs, some of which are highly skilled and require periodic certification. These positions include golf course superintendent, assistant superintendent(s), head mechanic, assistant mechanic(s), foreman or forewoman, spray technician(s), head gardener, gardener(s), irrigation specialist(s), and grounds crews. In total, superintendents and their staffs worked the equivalent of 13,841 full-time jobs to care for golf landscapes in 2000.

Use of Land and Water

California's golf course facilities in 2000 covered 137,297 acres. The area includes golf courses—tees, fairways, greens, roughs, sand bunkers, water bodies, and paved cart paths—practice greens, driving ranges, clubhouse grounds, undeveloped land, parking lots, surfaces of clubhouses, tennis courts and swimming pools, and other hardscape. Golf course landscapes exclude all impervious surfaces except cart paths. They occupied 120,907 acres and consist of golf courses, practice areas, clubhouse grounds, and undeveloped land. Superintendents used 340,406 acre-feet of water to irrigate 88,738 acres of golf courses, driving ranges, practice greens, and lawns around clubhouses in 2000.

Comparisons to Traditional Agriculture

Table 1 presents a comparison of resource use measured by revenue per acre of land and acre-foot of water among various agricultural commodities and golf courses. The results demonstrate the high variability in terms of revenue yield per acre between different crops. Field crops like grains and rice produced much less than a $1000 per acre in 2000 and less than $100 per acre-foot of water, while fresh tomatoes and some truck crops generated close to $10,000 per acre and more than $2000 per acre-foot of water. Table 1 shows expenditures to play and practice golf at golf course facilities were 8.8% of $19.904 billion, the farm-gate value in 2000 of all conventional agricultural commodities except apiary, dairy, livestock, and poultry products. The land area and water use on golf course landscapes were 1.4% of the

8.793 million acres of harvested land and 1.1% of the estimated 30.881 million acre-feet of water that growers used in 2000 to produce these conventional agricultural commodities.

Revenues were, on average, $14,431 per acre of land and $5,126 per acre-foot of water at golf courses, but only $2,264 per acre of land and $645 per acre-foot of water at conventional farms. Thus, revenues per acre of land and per acre-foot of applied water were, on average, 6.4 and 8.0 times larger at golf courses than conventional commodity farms, respectively. Revenues per acre of land and acre-foot of water were lower at golf courses than at conventional farms only for a few agricultural commodities, such as strawberries, flowers, and nursery products.

Because of the high value added of water for turfgrasses, golf courses in California were among the first to introduce modern irrigation practices, such as irrigation scheduling. Much of the lessons learned on golf courses were utilized to improve the technology and make it more affordable for low-value crops.

Table 1. Comparison of Revenues and Revenues Per Unit Land and Water for Agricultural Commodities and Golf Courses, 2000

Agricultural commodity	Revenues (product value) $1,000	Revenues per unit of water $/acre-foot	Revenues per unit of land $/acre
Grains	113,612	79	204
Rice	231,001	72	422
Cotton and cottonseed	1,025,523	367	1,122
Sugar beets	111,835	309	1,196
Corn	157,985	89	610
Beans, dry	56,700	205	506
Tomatoes, processing	617,190	742	2,277
Tomatoes, fresh market	333,840	2,840	7,800
Cucurbits	482,549	1,535	4,096
Garlic and onions	443,047	1,711	5,001
Potatoes	271,613	2,479	5,154
Other truck crops	8,607,152	5,724	9,429
Almonds and pistachios	919,789	376	1,601
Other deciduous nuts and fruits	1,308,940	571	2,294
Subtropical crops	1,103,130	752	2,948
Grapes, all	2,836,313	1,661	3,430
Alfalfa and other sources of hay	730,422	127	477
Safflower and other field crops	552,892	131	584
All crops	19,903,533	645	2,264
Golf courses	1,744,839	5,126	14,431

Source: Source: Hawkins, Tom. 2009. Agricultural Water Use Collection Program. Department of Water Resources, State of California, Sacramento SC, June 9.

Conclusion

A broad perspective on the agricultural sector is crucial for effective management of California resources. Turfgrass and other plants on golf courses are one of California's highest-value commodities in terms of either revenues per acre of land or acre-foot of water. As governments establish principles to allocate water and land resources among various activities, golf courses should be allowed to compete. Allocation of water away from low-value uses to golf course maintenance and other high-value uses could enable those who gain the water to compensate those who sacrifice their losses, and still be better off than they would have been without the reallocation.

Establishment of water trading could enable people to voluntarily make these reallocations. As producers of a high-value commodity, golf course superintendents would buy water from farmers of low-value crops. Similarly, future expansion of the golf sector as population ages globally may be an opportunity to increase value added derived from California's resources.

Einstein observed, "The significant problems we face cannot be solved at the same level of thinking we were at when we created them." The conflicts about water use and the challenges of rural development in California cannot be met if agriculture is only viewed as the production of food, fiber, and fodder. In recent years, policymakers and businesses have recognized potential economic contributions of agricultural production for fuel. Golf courses and other enterprises that supply venues for recreation can also add significant value to rural and other economies.

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