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NON-PREDATOR VERTEBRATE PEST DAMAGE IN CALIFORNIA AGRICULTURE: AN ASSESSMENT OF ECONOMIC IMPACTS IN SELECTED CROPS

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ABSTRACT: State-wide economic impacts of non-predator vertebrate pest damage were estimated for all pests causing damage in 19 California commodities. Average field-level damage estimates and vertebrate control costs were collected for each commodity, and across six production regions. Economic impacts were estimated by comparing simulated market outcomes in the absence of vertebrate pest damage with observed market outcomes. This analysis indicates that, for the 19 commodities considered, the economic cost of vertebrate pest damage ranged between $46.9 to $162.8 million during 1995 with a mean estimated impact of $95.9 million.

KEY WORDS: economic impacts, economics, vertebrate pests, wildlife damage

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INTRODUCTION

Vertebrate pests are responsible for significant damage to agricultural production systems in California. The animals causing damage include primarily small rodents, a variety of birds, and a few large mammals. As debate continues regarding whether and how these animals should be managed, agriculturists are operating under an increasingly stringent set of state and federal regulations that prescribe the method, place, and timing of control options. In addition to various types of use restrictions for toxicants, producers must also comply with provisions of the Migratory Bird Treaty Act and the Endangered Species Act, both of which influence when and how vertebrate pests may be controlled, if at all.

Although a number of analysts have estimated the economic impact of vertebrate-pest damage for individual commodities in California, few attempts have been made to quantify the state-wide cost of damage. In an effort to better understand these costs, a project was initiated with funding from the California Department of Food and Agriculture to estimate the economic impact of vertebrate damage in selected California commodities. This paper summarizes the main results of the authors' analysis.

VERTEBRATE PEST PROBLEMS IN CALIFORNIA AGRICULTURE

The list of vertebrate pest problems in California agriculture is potentially a long one. Virtually any living animal may cause significant economic harm if its numbers become large enough, or if its natural habitat becomes sufficiently limited. Indeed, the very classification of an animal as a "pest" is essentially an arbitrary decision that depends on one's perspective. This section briefly reviews the damages caused by a group of vertebrate species for which there is a clear consensus among agriculturists regarding their classification as pests. This does not mean there are not many other vertebrates that often act as pests and that cause significant economic injury, only that the authors have chosen to focus on these particular pests to keep the scope of their analysis within reasonable limits. For a more complete listing and discussion of vertebrate pest problems in California, see California Department of Food and Agriculture (1994).

Small Mammals

Rodents and jackrabbits account for a large fraction of total vertebrate pest damages and cause similar types of problems. They are destructive to vine and root systems, eat or otherwise destroy many vegetable, field, hay, and nut crops, and create burrow systems that can be destructive to crop growth and cause problems with mechanical harvesting operations. Ground squirrel and gopher problems are particularly widespread, and are considered the two most important vertebrate pests throughout the state. Although yield losses due to these animals are generally controllable in most crops and rarely exceed 2% or 3%, this is not always the case. For example, according to one University of California scientist, the Beldings ground squirrel is capable of causing yield losses of over 20% in alfalfa grown in the northeastern portion of the state, mainly because there are currently no effective controls available (Whisson 1997).

Meadow mice or voles are also important in many crops, and because they are capable of rapid reproduction, require careful monitoring. An industry source estimates current yield losses in most artichoke fields of the central coast to be 10 to 15% in a best-case scenario, with most growers spending between $80 to $100 per acre on control measures (Puck 1997). Voles also represent a significant problem in overwintered sugar beets according to Salmon, et al. (1984) who reported a 9% loss in total production on a 111 hectare commercial sugar beet field located in Northern California. A number of rats, especially the Norway rat, cause significant damage in orchards, and also transmit disease in dairy and poultry operations. Jackrabbits are also considered an important agricultural pest.

There is significant year-to-year variability in the damage created by small mammals due not only to variation in climatic conditions, but also to the degree of care taken in practicing control. Thus, although severe crop damage can generally be avoided, lack of appropriate control can lead to nearly complete crop loss in some cases. Another important source of heterogeneity in pest damage is geography. For example, Salmon (1987), using detailed rodenticide-use data from Tulare County, notes that the number of acres treated with rodenticides varies from 0.3 to 69.9% of total planted acres across 26 crops. If we suppose that treatment generally occurs where pest problems are most severe, these figures highlight the fact that pest damage varies considerably depending on location.

Most vertebrate control specialists view rodent control as preventive in nature. That is, if a little care is taken in ensuring that rodent populations are kept under control, then most, if not all, damage can be avoided. Although there are a number of non-chemical methods available for rodent control, most specialists see chemical methods as superior both in terms of cost and effectiveness. Toxicants used for control of rodents and jackrabbits include anticoagulants (chlorophacinone and diphacinone), zinc phosphide, strychnine, and fumigants (aluminum phosphide and gas cartridges). Although trapping can be effective under some circumstances, it is generally considered too time consuming and impractical with large populations. Ground squirrels, meadow mice, and rats are primarily controlled with anticoagulants or zinc phosphide, pocket gophers with strychnine, and rabbits with anticoagulants, trapping, shooting, and exclusion.

Large Mammals

Although most large mammals are known for their predatory behavior, some are also a nuisance in cropland. For example, coyotes often destroy plastic irrigation pipe in orchard and vineyard operations, which can disrupt irrigation timing and require costly, time-consuming repair efforts. One vineyard operator in Monterey County estimated a total annual cost of $3,503 for repair of coyote-damaged drip irrigation equipment on 378 acres, representing a cost of nearly $10 per acre (Scaroni 1997). Coyotes also cause significant harm to watermelon producers through destruction of the ripened fruit. Feral pigs are another important non-predator pest. They create damage to field crops through rooting and crop consumption, and destroy or foul feed and water sources in livestock operations. Both of these animals are generally controlled with hunting or trapping methods. In California, it is not uncommon for ranchers to promote private hunting of pigs on their land, and in some cases to even sell hunting rights.

Birds

Birds cause a wide variety of problems throughout California, and are generally difficult to control. Birds cause the greatest damage in fruit and nut crops, and in emerging crops, particularly lettuce. Damage to pistachio and almond orchards in the Central Valley have been well documented (Salmon, et al. 1986; Hassey and Salmon 1993), as well as to wild rice operations in Northern California (Gorenzel, et al. 1990). Bird damage in vineyards is also significant, and more important in table grapes because damaged fruit does not store well. The birds causing the greatest damage include the horned lark, crowned sparrow, house finch, blackbird, starling, and crow. Of these, only starlings may be controlled without restriction or some form of supervision by either the County Agricultural Commissioner (CAC), or the U.S. Fish and Wildlife Service (California Department of Food and Agriculture 1994). Generally, state and federal restrictions governing bird control are more widespread than with rodents and other vertebrate pests. In most situations, growers use a combination of sound and other scare tactics, trapping, and in some cases, shooting.

In many commodities, two or more of the pests described above may simultaneously cause damage. In the discussion of methods and results that follows, the authors measure the cumulative impact of each pest for each commodity.

METHODS

Data

The first step in the authors' analysis involved an extensive search of existing literature relating to wildlife damage in California. While numerous technical papers describing the efficacy of alternative pest-control options were found and reviewed, comparatively little attention has been focused in past research on the economics of vertebrate-pest control. Likewise, descriptive information on the incidence and severity of pest damage across the state was found to be extremely limited. Table 1 summarizes past studies used in this analysis.

Following a review of published literature, interviews were conducted with over 70 individuals who have knowledge of vertebrate-pest issues in California. The interviewees included university scientists, farm advisors, County Agricultural Commissioner (CAC) personnel, growers, and private pest-control advisors. A combination of descriptive and empirical information was collected through these interviews, with the questions tailored to the respondent and to his or her particular expertise.

Although reliance on expert opinion has well recognized limitations, it would be impossible to develop a statewide picture of impacts any other way. Furthermore, the authors incorporate uncertainty regarding expected impacts by specifying ranges for each of the key parameters in their impact model. This allows the authors to develop estimates of economic impact that reflect both uncertainty by experts regarding the level of damages in an average year, and variation in damages caused by unpredictable climatic and environmental factors. Table 2 presents average values for each of the key parameters used in the model. Also specified are low and high estimates for each parameter, and these were used to generate ranges of economic impacts as described below.

Based on initial data collection efforts, 19 crops were selected for which vertebrate-pest problems appeared to be particularly severe. For each crop, between two and seven key production regions were identified, paying particular attention to differences in the nature and severity of vertebrate-pest problems across each of the regions. Data from 1995 on harvested acreage, production, and average price were then collected for each crop/region combination from the California Department of Food and Agriculture. These data represented the base, or *status quo*, situation from which economic impacts were estimated.

Table 1. Published estimates of vertebrate damage in California.

Source	Crop(s) Considered	Summary of results
Crabb, Salmon, and Marsh	Pistachios	Reports 2 to 10% yield loss on 77% of state's acres. Estimated $1.8 million total loss.
Gorenzel and Salmon	Peaches and Prunes	Two case studies of gopher and rabbit damage in central valley orchards (Sutter and Fresno counties). Present discounted value of losses between $9,822 to $27,703 on 39 acres for prunes, and between $700 to $1,589 on 19 acres in peaches. These losses excluded rodent control costs.
Gorenzel, Marcum, and Salmon	Wild Rice	Reports at least a 5% yield loss after controls have been applied, and $85/acre control cost for control with highest benefit-cost ratio.
Hasey and Salmon	Almonds	3 to 4% crop loss from birds, mainly crows, in affected areas of northern California. Growers experiencing loss expressed willingness to pay on average $25/acre to reduce damage by 50%.
Salmon, Gorenzel, and Lickliter	Sugar Beets	Reports 9% crop loss in overwintered beets in northern California where no controls are applied.

Table 2. Average parameter values used in market simulation.

Crop	Yield Damage	Per-Acre Control Cost	% Acres Affected	Supply Elasticity	Demand Elasticity
Alfalfa	7.83	5	17	0.85	-1.30
Almonds	3.50	20	30	0.23	-0.57
Artichokes	15.00	90	70	0.46	-0.70
Carrots	0.62	5	40	0.80	-0.75
Cauliflower	0.50	5	40	0.80	-0.55
Citrus, Lemons	3.50	10	30	0.23	-0.41
Citrus, Other	0.50	5	30	0.23	-0.41
Grapes, Other	1.02	11	40	0.23	-0.35
Grapes, Table	3.50	26	40	0.23	-0.44
Lettuce	3.75	24	40	0.80	-0.75
Pistachios	5.75	20	40	0.23	-0.74
Potatoes	1.38	5	28	0.47	-0.22
Stone Fruits[1]	0.68	10	30	0.23	-0.47
Strawberries	1.28	10	40	0.53	-0.60
Sugar Beets	2.44	5	40	0.36	-0.42
Tomatoes, Fr.	1.38	5	30	0.85	-0.97
Tomatoes, Pr.	0.50	40	30	0.85	-0.97
Walnuts	2.88	14	40	0.23	-0.69
Watermelon	1.38	10	30	0.80	-0.53
Wheat	1.38	6	40	0.85	-1.30

[1]Includes apricots, cherries, nectarines, peaches, and plums.
Source: References in Table 1, and interviews with USDA, CAC, CDFA, industry, and university sources.

Measuring Gains and Losses

The methodology used for estimating impacts follows that developed in Lichtenberg et al. (1988), Zilberman (1991), and Hueth et al. (1998). This methodology integrates estimates of yield damage and per-acre control costs with market data to simulate shifts in production that would occur in the absence of pest damage, and the resulting changes in prices of agricultural commodities. With estimated changes in production and prices, economic impacts or changes in economic welfare were then calculated.[1] The authors incorporate uncertainty with regard to the underlying parameters in their model by simulating impacts under 1,000 different configurations of parameter values.

Economic welfare is defined as the sum of consumer and producer surplus, and producers are divided into two categories: those whose acres are affected by vertebrate pests, and those whose acres are unaffected. Consumer surplus measures the difference between the benefits derived from a certain level of consumption and the cost at the market, and producer surplus is simply a measure of producer profit. The total economic impact of vertebrate pest damage is then calculated as the difference between total economic welfare in the absence of vertebrate pest damage, and total economic welfare in the *status quo*.

The existence of vertebrate damage reduces total output and, therefore, results in higher market prices for agricultural commodities than would occur in the absence of damage. This represents an unambiguous loss to consumers who end up paying higher prices for food commodities, however, the implications for producers are less clear. Producers growing in areas unaffected by vertebrate damage unambiguously gain, because they receive a higher price for their produce than they would if all production regions were immune from damage. The remaining producers may gain or lose depending on how much prices rise. As production falls, producers in affected areas lose from the sale of less output, but also may gain since they are paid a higher price on each unit sold. The net effect on revenue is indeterminate, and depends on the extent to which market price responds to a decrease in output (i.e., on the price elasticity of demand), on the extent of yield damage, and on the level of vertebrate-control costs. If demand is price inelastic, then even a small reduction in quantity can have a large impact on market price. In this case, producers in affected areas can gain as a result of a contraction in their output.

Although somewhat counterintuitive, this observation is consistent with the practice in some agricultural industries to use supply control in order to "maintain stable prices." The difference here is that many growers are practicing supply control *involuntarily,* and furthermore, are not receiving any compensation for lost product. Thus, although vertebrate damage in some ways achieves an outcome similar to that of an explicit supply-control program, the distributional consequences of the supply control are very different. In particular, one segment of the industry—growers whose acres are unaffected by vertebrate damage—gain at the expense of another segment. The estimates of economic impact presented in the next section confirm these points.

[1]Space limitations preclude inclusion of the full model, however, details may be obtained upon request from the authors.

RESULTS

Table 3 presents impacts for each crop, aggregating across regions, and Table 4 presents producer impacts for growers in affected and unaffected regions. All estimates represent mean impacts, unless otherwise indicated. The first column in Table 3 reports the percentage increase in price resulting from vertebrate damage. The highest and lowest price rises are for artichokes (9.36%), and wheat (0.09%). This reflects significant yield damage and California's dominant position relative to the rest of the country in the case of artichokes, and moderate damage together with the relatively minor importance of California wheat in national and world wheat markets, in the case of wheat.

The next two columns contain losses to all producers, both those affected and unaffected by vertebrate damage, and to consumers. The negative values in the producer-loss column indicate that, in aggregate, producers generally gain from vertebrate damage. This occurs for two reasons: first, demand for most agricultural commodities is inelastic, meaning that a small reduction in supply increases price significantly. Thus, for growers in affected regions, the cost of vertebrate damage in terms of lost production and control expenditures are somewhat offset by higher prices. Second, growers in unaffected areas benefit directly from higher prices. The results in Table 3 indicate that, added across both groups, producers experience a net gain. The total gain to producers from vertebrate pest damage is estimated to be $17.9 million in a typical year, while consumers lose approximately $113.8 million.

The final three columns report total welfare loss, representing the sum of producer and consumer losses. Recall from the previous section that economic impacts for each crop were computed one thousand times, with each iteration representing a different configuration of parameter values. Thus, the first total-welfare loss column reports x which is defined as the number such that 5% of simulated outcomes lie below x. Similarly, the next column reports y which is defined as the number such that 5% of all simulations lie above y. The final column contains the mean total welfare loss. Thus, in 1,000 simulations, 5% of the estimated total welfare loss calculations were smaller than $46.9 million, 5% were greater than $162.8 million, and on average were estimated at $95.9 million. This variability highlights the significant uncertainty associated with the underlying parameters of the analysis. Table 3 is also useful for comparing losses across commodity groups. Damage in vegetable crops is responsible for the largest component of total economic impact with average losses of $32.4 million. Fruits, nuts, and field crops then follow with total impacts of $25.2 million, $21.0 million, and $17.2 million, respectively.

An important drawback of reporting aggregate losses as in Table 3 is that doing so ignores the fact that growers who gain as a result of pest damage, do so at the expense

Table 3. Summary of economic impacts by crop.

Crop	Price Change (percent) ($1,000)	Producer Loss ($1,000)	Consumer Loss ($1,000)	Total Welfare Loss λ=0.05 ($1,000)	Total Welfare Loss λ=0.95 ($1,000)	Total Welfare Loss Average ($1,000)
Vegetables						
Artichokes	9.36	-1,031	6,339	3,698	7,086	5,309
Carrots	0.32	-88	1,022	193	1,430	934
Lettuce	1.90	-1,902	17,306	7,144	27,405	15,403
Tomatoes, Fr.	0.64	-261	2,106	837	3,672	1,845
Tomatoes, Pr.	1.07	1,233	7,660	5,785	13,155	8,893
Total		-2,049	34,433	17,657	52,748	32,384
Fruits						
Apricots	0.46	-224	622	196	768	398
Cherries	0.58	-327	780	196	939	453
Citrus, Lemon	1.16	-1,972	4,278	930	4,203	2,306
Citrus, Other	0.31	-398	1,427	463	1,586	1,029
Grapes, Other	0.48	-4,429	13,195	3,113	15,141	8,765
Grapes, Table	1.57	-6,154	13,794	2,984	14,012	7,640
Nectarines	0.62	-192	644	180	937	453
Peaches	0.62	-700	2,006	639	2,499	1,307
Plums	0.66	-74	389	136	604	315
Strawberries	0.75	-1,209	3,783	284	6,138	2,574
Total		-15,679	40,918	9,121	46,827	25,240
Nuts						
Almonds	0.97	-4,082	17,596	5,678	23,425	13,515
Pistachios	2.10	-501	3,831	744	6,769	3,329
Walnuts	1.13	-565	4,747	1,869	8,313	4,182
Total		-5,148	26,174	8,291	38,507	21,026
Field Crops						
Alfalfa	1.21	3,401	9,803	9,348	18,702	13,204
Potatoes	0.55	-157	497	174	488	340
Sugar Beets	0.61	-503	1,796	779	1,987	1,293
Wheat	0.09	2,238	172	1,502	3,530	2,410
Total		4,979	12,268	11,803	24,707	17,247
Grand Total		-17,897	113,793	46,872	162,789	95,897

Source: Calculated.

Table 4. Producer impacts.

Crop	Producer Surplus Change		Producer Loss/Revenue in Affected Areas	Total (1)+(2) ($1,000)
	Affected Areas (1) ($1,000)	Unaffected Areas (2) ($1,000)		
Vegetables				
Artichokes	-1,049	2,079	3.27	1,030
Carrots	-527	615	0.41	88
Lettuce	-8,684	10,586	2.45	1,902
Tomatoes	-6,903	5,930	1.36	-970
Total	-17,163	19,210		2,050
Fruits				
Citrus	-709	1,090	1.72	358
Grapes, Other	-2,225	8,379	1.19	7,640
Grapes, Table	-3,519	7,949	0.87	4,430
Strawberries	1,073	2,281	0.54	1,208
Total	-5,380	19,699		13,636
Nuts				
Almonds	-8,359	12,440	2.78	4,081
Pistachios	-1,853	2,354	4.74	501
Walnuts	-2,310	2,877	2.82	567
Total	-8,816	17,671		5,149
Field Crops				
Alfalfa	-8,880	5,894	7.75	-2,986
Potatoes	-143	299	0.39	156
Sugar Beets	-581	1,083	1.44	502
Wheat	-2,342	102	3.62	-2,240
Total	-11,946	7,378	3.30	-4,568
Grand Total	-43,305	63,958		16,267

Source: Calculated.

of affected growers. Table 4 highlights this fact. The first two columns report losses to growers in affected and unaffected regions, respectively. The next column reports losses as a fraction of total grower revenue for growers in affected regions, and the final column reports total grower losses. For example, artichoke growers as a whole likely gain from vertebrate damage, but this hides the fact that growers in affected regions lose over $17 million annually, while growers in unaffected areas gain over $19 million annually.

Also from Table 4, strawberry growers in both affected and unaffected areas gain from vertebrate damage. This occurs because average yield damage and control costs are fairly low, while the demand for strawberries is fairly inelastic. In contrast, although wheat growers in California also experience fairly light damage, there is nevertheless a significant cost. This occurs because the demand for California wheat is very elastic, so that even a large change in the total supply of California wheat will have little or no influence on the price received by the state's growers. As a fraction of grower revenue, losses in artichokes and alfalfa are highest. Profit margins are tight for most agricultural enterprises, and losing 3 to 5% of gross revenue can be critical. Lettuce, nut crops, sugar beets, and wheat also experience significant damage as a fraction of grower revenue.

CONCLUSION AND DISCUSSION

This study estimates the economic impact of non-predator vertebrate pest damage in 19 California crops. Measuring the economic impact from vertebrate pest damage at the state level is complicated by the fact that existing evidence on crop damage at the field level is scarce, and because field-level damages vary considerably across crops and regions. The authors' analysis disaggregates impacts across these dimensions to convey the localized nature of vertebrate damages, and also presents a range of impacts that are meant to convey uncertainty associated with the underlying parameters of their model.

Overall, their estimates indicate that the economic impact from vertebrate pest damage lies between $46.8 million to $162.8 million, with a mean estimated impact of $95.9 million. These results represent a lower bound on the total impacts of vertebrate damage in California because only a subset of all agricultural activity in the state was considered. Furthermore, there are many agriculture-related vertebrate pest problems that are not considered. For example, burrowing rodents create significant damage in irrigation canals, and some agricultural pests serve as sources of disease transmission to urban areas. Also, aggregate impacts hide the often crop- and location-specific nature of vertebrate damage. Finally, the impacts reported in this study do not address the potential impact of vertebrate pest damage with further restrictions or in the absence of existing controls.

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