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Farm practices for food safety: an emerging threat to floodplain and riparian ecosystems

Sasha Gennet[1*], Jeanette Howard[1], Jeff Langholz[2], Kathryn Andrews[1], Mark D Reynolds[1], and Scott A Morrison[1]

Floodplain and riparian ecosystems are noteworthy for their biodiversity conservation value as well as for their widespread conversion to agriculture. Recent evidence indicates that the conversion of remaining habitat may be accelerating because of a new threat: on-farm practices meant to promote food safety. Nationwide, US fruit and vegetable farmers report being pressured by commercial produce buyers to engage in land-use practices that are not conducive to wildlife and habitat conservation, in a scientifically questionable attempt to reduce food-borne illness risk. We measured the extent of impacts from some of these practices in a leading produce-growing region of California. Over a 5-year period following an outbreak of toxic *Escherichia coli* from spinach, a crop grown extensively in the region, 13.3% of remaining riparian habitat was eliminated or degraded. If these practices were implemented statewide, across all crops, up to 40% of riparian habitat and 45% of wetlands in some counties would be affected. This study highlights the importance of managing farms for both food safety and ecological health through the use of an evidence-based, adaptive management approach. Ongoing biodiversity loss and global integration of the food supply make these findings relevant wherever produce is grown.

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As global demand for food continues to rise, sustaining and enhancing agricultural productivity is becoming increasingly important (Tilman *et al*. 2011). Intact ecosystems and ecological processes play a role in agricultural productivity by providing natural benefits such as soil fertility, water quality, groundwater recharge, and pollination services (Zedler 2003; Chan *et al*. 2006; Garibaldi *et al*. 2011). However, land clearing and farming activities cause extensive habitat loss and degradation, with associated impacts on biodiversity (MA 2005).

Natural habitats near farms and their associated ecosystem services are being further jeopardized in an attempt to reduce already-low risk from food-borne pathogens. In recent years, outbreaks of food-borne pathogens from produce have occurred in the US and Europe, intensifying scrutiny of on-farm operations and practices to address potential sources of contamination (Beretti and Stuart 2008; Beretti 2009). Some of the new practices, particularly those targeted at eliminating wildlife and non-crop vegetation, do not have demonstrated risk-reduction benefits but, as we show in this paper, are likely having measurable environmental costs.

Before 2006, rigorous food safety standards for produce were not consistently enforced across the produce sector. An outbreak of *Escherichia coli* serotype O157:H7 in California-grown, bagged spinach that year eroded consumer confidence and resulted in a US$350 million loss to the leafy greens industry as consumers purchased less spinach (CDC 2006; Weise and Schmit 2007). Since then, outbreaks of pathogenic *E coli* and *Listeria monocytogenes* in 2011 in Europe and the US have intensified the urgency behind addressing food safety for consumers (eg Muniesa *et al*. 2012). In the US, and California in particular, three primary strategies for preventing food-borne illness in produce have been promoted: (1) industry-led development of publicly disclosed standards, such as the California Leafy Green Handler Marketing Agreement (LGMA); (2) proprietary on-farm standards required by corporate buyers and administered through third-party auditors by farm inspections; and (3) the federal Food Safety Modernization Act (FSMA) of 2011 and associated regulations proposed by the US Food and Drug Administration in 2013.

Corporate buyers of leafy greens developed the most sweeping food safety standards in the immediate aftermath of the 2006 *E coli* outbreak. Buyers established individual metrics for on-farm practices, enforced through regular inspections and auditing of farm fields. These metrics are generally not shared with the public, but certain elements have been described in the media and revealed through farmer surveys. For example, an article published in the newspaper *USA Today* quoted industry executives as saying that their companies will not purchase crops grown within 150 yards (~145 m) of rivers or habitat that attracts wildlife (Schmit 2006). In a 2007 study (Beretti and Stuart 2008), 89% of surveyed farmers in seven California counties, mostly within the coastal counties between Los Angeles and San

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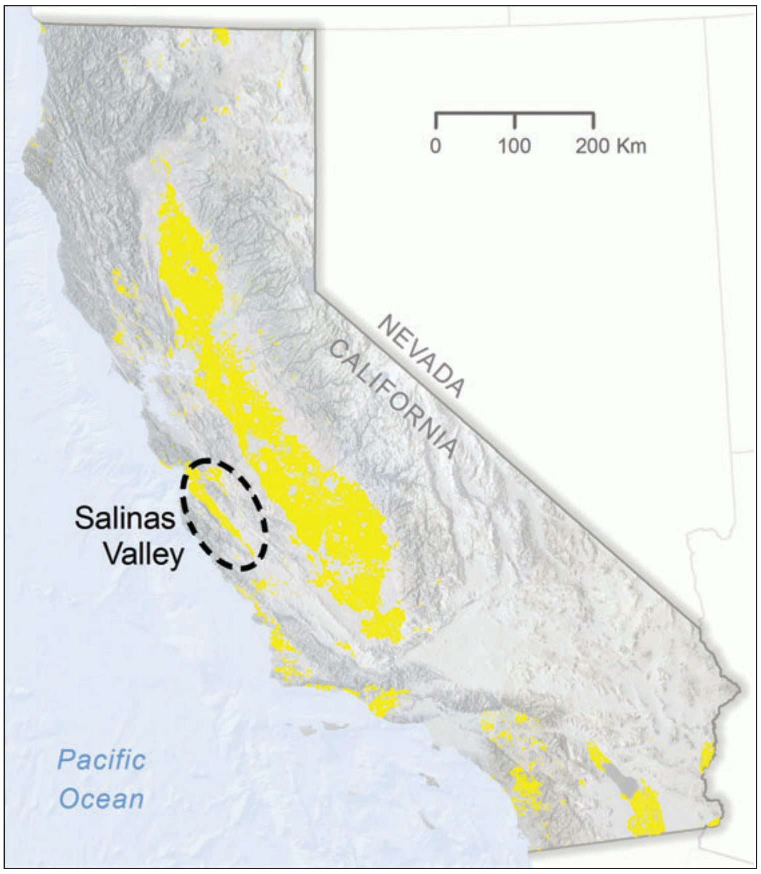

Figure 1. *Agricultural land cover in the US state of California (yellow shading). The Salinas Valley is circled.*

resources are impacted despite scant evidence that they constitute a measurable risk. For example, in Montana from 1996 to 1997, large numbers of bison were culled to reduce potential pathogen transmission to domestic cattle despite a lack of evidence that such efforts would achieve this goal (White *et al.* 2011).

Here, we describe the emergence of food safety as a biodiversity conservation issue, quantify some of the effects of farming practices implemented to reduce risks from wildlife in an important agricultural region of California, and calculate the potential extent of impacts if these practices were to be implemented at a larger scale and across more crop types. We also suggest a path forward: a multi-objective, evidence-based, adaptive management framework that explicitly assesses risk to environmental quality and human health. This approach would limit further similar destruction of natural habitat within or adjacent to agricultural regions and would help to protect ecosystem services.

Francisco, reported yielding to pressure from auditors, inspectors, and other food safety professionals to implement on-farm food safety measures that were environmentally detrimental. Consequences of non-compliance can include rejection of product from portions or entire fields by buyers. Practices include removing non-crop vegetation to reduce wildlife presence (eg deer), treating irrigation reservoirs and other water bodies with chemicals toxic to amphibians and fish, installing fencing to prevent field incursions from wildlife, and using poison bait and traps to control rodents. A follow-up survey in 2009 confirmed these findings and reported that similar guidelines were expanding to include crops typically cooked before consumption despite the much lower risk of bacterial contamination associated with such crops (Lowell *et al.* 2010).

The evidence indicating food safety risk as a result of exposure to wildlife remains scarce and incomplete (Ilic *et al.* 2012). Although some wildlife species may carry certain pathogens, infection rates are low and studies have failed to demonstrate a causal link between wildlife presence and the incidence of food-borne illness (Langholz and Jay-Russell 2013). Wildlife does not constitute a major source of *E coli* O157:H7 or other harmful pathogens (Ferens and Hovde 2011). The dramatic measures taken to reduce perceived or potential risk fit a pattern in wildlife–human conflicts in which natural

Methods

Study area

To determine the extent to which the aforementioned practices may affect natural habitat, we calculated loss and degradation of vegetation in the Salinas River Valley of California (Figure 1). We chose the Salinas River Valley as a case study for three reasons. First, this area is one of the nation's top producers of fresh produce (USDA 2009). Known as "America's salad bowl", it provides 70% of all leafy greens grown in the US and sets de facto standards that are followed in other major produce-growing regions in the US and beyond. Second, no other crop-growing region has received more attention with respect to the environmental implications of practices implemented in the name of food safety, despite the 2006 outbreak originating elsewhere. Finally, the Salinas Valley is an area of exceptional ecological importance, and where biodiversity values are particularly high. For example, the 260-km-long river system provides stopover habitat for migratory birds along the Pacific Flyway, supports several federally protected endangered species, enables wildlife movement between the river mainstem and tributaries, and influences the health of the Monterey Bay National Marine Sanctuary, one of the nation's largest marine protected areas, into which it drains.

Measuring local habitat change

We measured the changes to riparian habitat and wetlands in the Salinas River floodplain between 2005 (before the spinach *E coli* outbreak) and 2009 (3 years after first implementation of food safety practices). We delineated and classified vegetation polygons within 0.4 km of the Salinas River, along the lower 93 km of the river and major tributaries, using National Agriculture Imagery Program aerial imagery. We applied a 0.1-ha minimum mapping unit and identified vegetation types according to the California Manual of Vegetation (Sawyer *et al.* 2009). The vegetation change analysis conservatively differentiated anthropogenic changes (due to agricultural or urban encroachment) from natural changes (due to fluvial events); only changes at the margins of farm fields, and not those observed adjacent to the river channel, were assumed to be related to food safety (Figure 2).

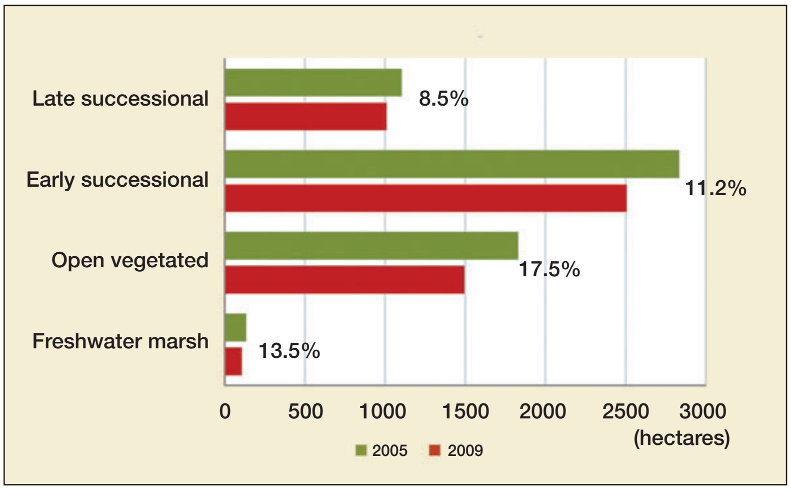

Figure 2. *Habitat loss by vegetation type between 2005 and 2009.*

We classified riparian and wetland communities in the 15 378-ha study area. These included open vegetated community types in the active channel, freshwater wetlands, scrub and mid-seral to late-seral woodlands, and forests characterized by mature cottonwood, oak, and sycamore. Each of these habitats supports a distinctive species assemblage, with some including rare and protected species (Sawyer *et al.* 2009).

We also measured changes to habitat corridors for wildlife. A previous study had identified 20 areas with the potential to support wildlife movement to and from the river and adjacent foothills (McGraw and Boldero 2008). These are either tributaries or points at which the foothills of surrounding mountains are in direct contact with the riparian vegetation. We measured habitat connectivity loss in these corridors in two ways. First, we calculated vegetation changes between 2005 and 2009 within these corridor polygons using the same aerial imagery and photo-interpretation methods described above. We then calculated the extent and type of fencing on farms intersecting these corridors, based on observations made from fixed-wing aircraft and groundtruthed in May 2011.

Modeling potential statewide habitat change

Evidence suggests that buyers and/or regulators are requiring environmentally concerning food safety practices well beyond the Salinas Valley. First, as noted above, farmers surveyed in seven coastal counties between Los Angeles and San Francisco indicated that they had implemented environmentally destructive food safety practices due to pressure from buyers. Second, survey respondents indicated buyers were expanding the list of crops that would require these practices, including crops that are cooked before eating. Third, federal standards for food safety certification (USDA 2012) incentivize farmers nationwide to eliminate habitat and deter or kill wildlife. Specifically, farmers must receive a score of 80% or higher to pass the US Department of Agriculture's audit and lose points if they do not take measures to deter wildlife entry into crop production areas. Finally, during a series of stakeholder forums attended by one of the authors, farmers from the Midwest, Mid-Atlantic, Northeast, Southeast, and West Coast states expressed concerns about potential habitat and wildlife management requirements under FSMA regulations (PSP 2010). Given the recent (2013) publication of the proposed regulations and national scope of this issue, it is worth examining the impact of food safety buffer zones on larger geographical scales.

We calculated the potential extent of impacts if the published corporate buyers' metric of 120-m bare ground buffers were fully implemented statewide. Although this width may be almost impossible to achieve on some farms, this standard was released by a leading corporate buyer subsequent to the spinach *E coli* outbreak (Schmit 2006) and therefore could be a realistic scenario. We used a geographic information system to approximate a 120-m buffer zone around two targeted agricultural crop scenarios; these crop scenarios were compiled from publicly available data (CDWR 1994–2010). The first scenario focuses on those crops reported by farmers to be the most affected by corporate food safety requirements: leafy greens and truck crops (eg artichokes, asparagus, cruciferous vegetables, green beans, root vegetables, melons, peas, tomatoes, flowers, bush berries, strawberries, and peppers). The second scenario reflects agricultural products that could be targeted if food safety programs are expanded more broadly, including the leafy greens and truck crops described above plus deciduous nuts and fruits, citrus, field crops (cotton, grain, corn, sunflowers), and rice.

For each county, we calculated the total amount of natural vegetation within the buffer zones; this amount represents total potentially impacted habitat. The best available habitat data statewide for our purpose were part of the multi-source, land-cover digital dataset published by the State of California (CDF 2002). Because of the coarse resolution of the land-cover data (100 m × 100 m pixel size) and the compilation methodology, smaller or linear

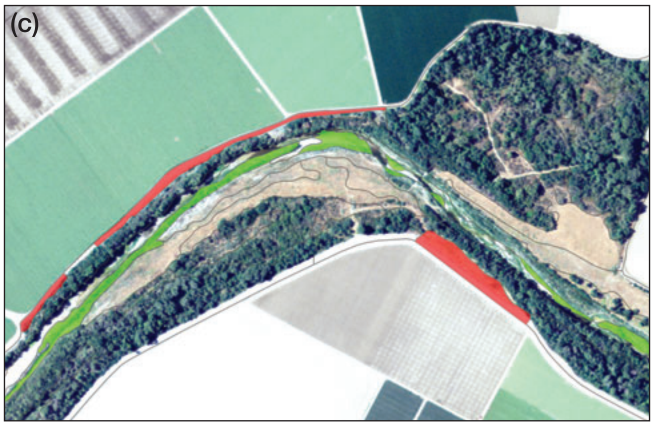

Figure 3. *Examples of farm-field buffers. Red polygons delimit vegetation change likely due to food safety measures. Green polygons in final aerial image delimit vegetation change within the river channel that is not food-safety related.*

habitat features, such as riparian corridors and wetlands, are likely underrepresented.

Results

Our findings suggest that food safety practices encouraged on farms (1) have already substantially affected habitat adjacent to farm fields in our study area and (2) could threaten habitat, with associated biodiversity and ecosystem function, in commercial produce-growing regions elsewhere in California and potentially around the world.

Local habitat loss, degradation, and connectivity

Between 2005 and 2009, (1) 13.3% of riparian and wetland vegetation along the Salinas River either was converted to bare ground or crops, or was observably altered and degraded (Figures 2 and 3) and (2) 8.2% of existing vegetation was lost in the 20 identified Salinas River Valley wildlife corridors. The latter losses brought the total natural vegetation cover in these corridors to 51.7%. In addition, our analysis revealed widespread efforts to limit wildlife movement. Of the 20 identified wildlife corridors in the valley, 75% were at least partially fenced during the 5-year study period. Most of this fencing (81%) was 1.8–2.5 m (6–8 ft) tall mesh targeted at large- and medium-bodied wildlife species or shorter silt fencing targeting amphibians and small mammals. The remainder was 1.8 m or lower barbed wire fence designed primarily for cattle.

Potential statewide impacts

Under the first scenario (leafy greens and truck crops), a 120-m (~400-ft) buffer around crop areas would impact 40 523 ha of natural habitat across 45 California counties. The greatest potential impact would be on grasslands (19 689 ha, 49% of total impact), riparian (6061 ha, 15% of total impact), and oak woodlands (4773 ha, 12% of total impact). Other affected habitats include coastal scrub (3180 ha, 8% of total impact) and wetlands (1656 ha, 4% of total impact).

Under the second scenario (all crops), a 120-m buffer around crop areas would impact 203 132 ha of natural habitat across 45 California counties (WebTable 1). The greatest potential impact would be on annual grasslands, riparian areas, and wetlands (Table 1). Counties with > 20% predicted loss of riparian habitat include: Colusa, Glenn, Kings, Sacramento, San Joaquin, Santa Cruz, Sutter, Tehama, and Yolo. Counties with > 20% predicted loss of current wetland area include: Yolo, Stanislaus, Sutter, San Joaquin, Colusa, Butte, Glenn, and Yuba, with the lattermost predicted to lose 45% of current wetland area.

Discussion

Our analyses of vegetation change and fencing in the Salinas River Valley – an important agricultural region – strongly suggest that food safety-driven farming practices have been associated with rapid loss and degradation of what was already greatly reduced natural habitat and ecological integrity. These changes will affect terrestrial and aquatic species, including wide-ranging mammals dependent on migration and dispersal to maintain long-term populations; federally threatened steelhead (*Oncorhynchus mykiss*) that require shaded, cooler waters; and neotropical migratory birds that utilize mature riparian vegetation.

We are unaware of any factors other than food safety that would drive growers to expend resources on these types of fences and habitat alterations. Although we cannot make an absolute causal link between the changes observed on each property and food safety issues, the 2008 and 2009 farmer surveys provide compelling evidence that throughout the study area these types of land-use changes are likely caused by pressure from buyers (Beretti and Stuart 2008; Beretti 2009).

Table 1. Potential loss or degradation of habitats in California counties from implementation of 120-m (400-ft) buffers, Scenario II (all crops)

	Potential extent of impacts (ha)	*Relative %*	*Total %*
Annual grasslands	114 862	57	3
Riparian	24 752	12	4
Oak woodlands	21 807	1	1
Wetlands	14 071	7	7
Coastal scrub	12 851	6	3
Chaparral	8398	4	<1
Montane hardwoods	6391	3	<1

Notes: "Potential extent of impacts" is statewide total hectares. "Relative %" is the percent contribution of potential loss from each habitat type relative to the statewide total. Only habitat types ≥1% are included, so column does not sum to 100. "Total %" is the percent of the total that the potential impacts represents.

Unfortunately, there is little publicly available information on corporate metrics for food safety, so we cannot directly measure or calculate the extent to which these practices are being applied elsewhere. However, the limited evidence from newspaper reports and grower surveys suggests that at least some large buyers are requiring sterilization practices far in excess of scientifically informed, adaptively developed standards, and are doing so across multiple regions and crop types (Schmidt 2006; Beretti 2009; PSP 2010). In our assessment of potential statewide impacts we show that, if applied as these sources suggest may be happening, on-farm food safety practices would have severe impacts on floodplain and riparian systems throughout California, despite relatively strong environmental laws and regulations. Further, given that many large buyers of produce are multi-national corporations, practices developed in one region could quickly become standard in other regions. Recent high-profile outbreaks of food-borne pathogens in Europe suggest that food safety is a global issue. These practices not only affect wildlife but may also threaten agriculture by eroding ecosystem services (Zedler *et al.* 2003). The value of embedded natural lands in agricultural landscapes is high (Garibaldi 2011; Kremen and Miles 2012), and includes: (1) regulating services (controlling floods, purifying water, keeping diseases in check, offering resilience to climate change); (2) provisioning services (food, fuel, fresh water); and (3) cultural services (scenic beauty, open space; MA 2005). At least some of these benefits are being threatened by current food safety risk reduction measures.

Numerous studies have shown that non-crop vegetation in and around fields can substantially reduce pollution and the survival and movement of pathogens (see Lowell *et al.* 2010 for a review). One study tested the effectiveness of *E coli* filtration through vegetated buffers on cattle grazing lands in California (Tate *et al.* 2006); although the efficiency of filtration depends on water flow, soil type, and slope, vegetative buffers were effective in reducing inputs of water-borne *E coli* into surface waters. A review of 40 field trials indicated that vegetative systems within agricultural waterways, basins, or ditches can achieve major reductions in pollution, including that related to pathogenic bacteria (Koelsch *et al.* 2006). Likewise, reductions greater than 90% for fecal coliform bacteria have been regularly observed as a result of vegetated treatment systems (Kadlec and Knight 1996). These findings (1) highlight an important ecosystem service provided by non-crop vegetation in and around fields and (2) raise important questions about the science related to the requirement of bare ground buffers.

Furthermore, the fencing and loss of corridor vegetation not only impact wildlife but also represent a substantial expense for farmers in terms of implementation and maintenance. A survey of leafy greens growers found that these growers' costs for modifications made specifically for LGMA compliance averaged US$21 490, or US$33.61 per acre (Hardesty and Kusunose 2009). Additional economic impacts could occur in cases where a farmer does not control land adjacent to fields, and therefore must create the bare ground buffer within an area previously used for crop production.

We propose that the solution to maximizing benefits from natural habitat near agricultural land while minimizing risk of food-borne contamination from wildlife is to consider both objectives – safe food and healthy ecosystems – and identify trade-offs as part of a transparent, adaptive, evidence-based process (Stankey *et al.* 2005; Bradford and D'Amato 2012). The LGMA process approaches this ideal and should be used as a model.

From an economics perspective, safe food and healthy, productive natural and agricultural systems have considerable positive externalities. Therefore, without regulation or other intervention that forces both to be managed together, less than the socially optimal quantity of these goods will be protected. Food safety metrics that internalize a fuller range of costs and benefits can be built into industry and corporate policy, but without a scientific assessment of potential impacts, market signals and government policies can drive land-use changes that have wide-ranging negative environmental effects. The dramatic expansion of corn and its unintended consequence of substantial water quality degradation in the midwestern US as a direct response to federal subsidies for ethanol production and the Renewable Fuels Standard provide a cautionary tale (Donner and Kucharik 2008). An adaptive management approach – whereby new information is incorporated through systematic review and risk analysis into policy and practice as it becomes available – would allow for the uncertainty inherent in agroecological systems while providing a framework for co-management of ecological and food safety objectives. Incorporating conservation goals alongside pathogen risk reduction, including actions such as riparian and aquatic habitat protection and enhancement of wildlife corridors, could help safeguard water quality, ecosystem services, agricultural sustainability, and biological diversity and set a standard for multi-objective management.

The industry and agencies charged with regulating food safety and the environment have an opportunity to lead the agricultural sector in developing standards that minimize the risk of food-borne pathogens while ensuring sustainable agricultural and intact ecological systems. Decision-making processes should be transparent, should incorporate both food safety and environmental quality objectives, should be science-based, and should directly engage key stakeholders, including farmers, buyers, regulators, and scientists. Continued investment in research that attempts to improve understanding of vector transport is critical, and pursuing transparent, multi-objective decision-making would help ensure both ecological and public health benefits.

Conclusions

We documented a 13% loss of wetland and riparian habitat in California's Salinas Valley at a time and in a location associated with aggressive implementation of on-farm food safety practices. The vegetation change analysis corroborates the findings of previous studies in which farmers indicated yielding to pressure to eliminate wildlife and habitat to meet food safety requirements. Moreover, we have shown that statewide implementation of one food safety practice – a 120-m bare ground buffer around crop areas – could result in the loss of an additional 203 132 ha of important habitat in California alone. This would entail eight counties losing more than 20% of their remaining wetlands, and nine counties losing more than 20% of their riparian habitat.

Given the important benefits that ecosystems and natural communities provide to agricultural productivity and to society in general, as well as the lack of evidence implicating wildlife in food-borne illness outbreaks, we recommend a science-based risk management approach, based on co-management for food safety and ecological health. By pursuing both goals in an adaptive management framework, society can more assuredly advance safe and sustainable agriculture in California and elsewhere.

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WebTable 1. Potential loss of habitats in California counties from implementation of 120-m (400-ft) buffers, Scenario II (all crops)

County	Grassland	Oak woodland	Coastal scrub	Wetland	Chaparral	Montane hardwood	Riparian	Total
Alameda	318	69	0	5	0	13	2	407
Amador	388	110	0	9	5	246	9	767
Butte	3783	848	0	2369 (24.9)	0	334	964	8298
Calaveras	742	145	0	8	113	608	0	1616
Colusa	2380	44	0	3198 (31.7)	5	0	596 (31.9)	6223
Contra Costa	1042	73	0	400	1	9	130	1655
Del Norte	35	0	17	6	0	18	29	105
El Dorado	0	0	0	0	0	0	0	0
Fresno	7631	1210	0	825	0	223	220	10 109
Glenn	3349	22	0	1758 (25.2)	5	7	501 (22.8)	5642
Humboldt	111	1	1	36	42	90	109	390
Imperial	0	0	0	205	0	0	0	205
Kern	13 187	131	0	523	0	28	20	13 889
Kings	3889	16	0	237 (15.6)	0	0	289 (24.4)	4431
Lake	840	787	0	104	784	899	0	3414
Lassen	73	0	0	21	39	8	2	143
Los Angeles	7	0	8	0	0	0	0	15
Madera	5923	546	0	272	0	33	123	6897
Marin	80	17	26	6	0	28	12	169
Mariposa	23	22	0	16	5	80	0	146
Merced	7641	625	0	759	0	164	290 (26.1)	9479
Modoc	22	0	0	65	0	0	7	94
Monterey	3872	1514	178	416 (19.0)	3	0	1361 (18.2)	7344
Napa	185	69	0	17	35	263	18	587
Placer	2569	773	0	272 (11.7)	33	329	103	4079
Plumas	3	0	0	0	3	8	0	14
Riverside	1083	157	1413 (10.2)	76	687	0	119	3535
Sacramento	2774	75	0	1411 (18.9)	0	31	808 (22.5)	5099
San Benito	1704	174	3	11	0	0	6	1898
San Bernardino	765	5	459	19	101	130	56	1535
San Diego	2288	1063	4899 (32.5)	208	4365	146	586	13 555
San Joaquin	4828	251	0	1000 (33.7)	5 (29.4)	247 (30.1)	2760 (38.8)	9091
San Luis Obispo	4781	3780	466 (20.8)	45	31	92	14	9209
Santa Barbara	3617	1593	1583 (50.1)	44	915	32	760	8544
Santa Clara	9	1	0	0	0	0	0	10
Santa Cruz	571 (10.1)	422 (10.5)	195	84	10	1	5 (26.3)	1288
Shasta	325	433	0	202	401	108	79	1548
Sierra	1	0	0	0	0	0	0	1
Siskiyou	96	0	0	55	23	47	0	221
Solano	1198	252	0	258	0	49	281	2038
Sonoma	533	24	2	77	9	648	109	1402
Stanislaus	6770	958	0	545 (34.7)	10	407 (17.8)	891 (16.5)	9581
Sutter	2378 (15.0)	126	0	2562 (33.1)	0	4 (40)	944 (39.9)	6014
Tehama	4374	280	0	1334 (19.1)	31	26	943 (20)	6988
Trinity	42	0	0	0	21	67	1	131
Tulare	11 090	3711	0	766	0	612	124	16 303
Tuolumne	42	15	0	2	61	181	0	301
Ventura	1087	731	3609	150	645	0	1009 (12.5)	7231
Yolo	3422	422	0	2117 (25.3)	13	13	669 (41.4)	6656
Yuba	3011	313	0	932 (44.3)	0	170	449 (11.4)	4875
TOTAL	**114 882**	**21 808**	**12 859**	**23 425**	**8401**	**6399**	**15 398**	**203 172**

Notes: Values denote hectares, with corresponding percentages (in parentheses) if greater than 10%.