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# Economic Impacts of Yellow Starthistle on California Ranchers


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**May 2006**

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## Abstract

While the significant ecosystem damage caused by invasive weeds has been well documented, the economic impacts of specific invasive weed species are poorly understood. Yellow starthistle (*Centaurea solstitialis* L., hereafter YST) is the most widespread non-crop weed in California, resulting in serious damage to forage on natural range and improved pasture. A survey was administered to California cattle ranchers to investigate YST infestation rates, loss of forage quantity and value, and control or eradication efforts. The results were used to estimate county-wide economic losses for three focus counties, as well as state-wide economic losses, due to YST in California. Total losses of livestock forage value due to YST on private land for the state of California are estimated at $7.96 million/year, with ranchers' out-of-pocket expenditures on YST control amounting to $9.45 million/year. Together, these costs are the equivalent of 6-7% of the total annual harvested pasture value for the state. Therefore, while the impacts are relatively small within the statewide total agricultural production system, costs due to YST infestation significantly constrain California's livestock grazing sector.



**Keywords:** nonnative species, invasive weeds, yellow starthistle, ranching profitability, forage, livestock.

**Acknowledgements:** This research was funded in part by a grant from the California Department of Food and Agriculture. The contents of this manuscript do not necessarily reflect the views of the California Department of Food and Agriculture or any other organization with which any of the authors are affiliated. We thank Joseph DiTomaso of the University of California – Davis for suggestions and comments in the survey design phase of this project, and Michael Pitcairn of CDFA for discussions regarding the initial findings and implications of the survey. We are indebted to Susan LaGrande of the California Cattlemen's Association for lending enthusiastic support to make implementation of the rancher survey a possibility. Finally, we thank Sue Strom of the University of Nevada and Carrie Bartzen of the University of Wisconsin for assistance with survey implementation and data entry.

Nonindigenous invasive weed species can have substantial impacts on forage quantity and quality, increasing management costs, imposing land-use changes and thereby reducing ranch profitability. Environmental damage and losses due to the approximately 50,000 nonindigenous species in the United States have been estimated at more than $136 billion per year, with $6 billion due to weeds in pastures (Pimentel et al. 2000). Although the impacts of invasive weeds on livestock grazing are significant, relatively few studies have estimated the economic impacts of specific weed species on the ranching sector. Notable exceptions include studies of leafy spurge (*Euphorbia esula* L.) (Leistritz et al. 1992; Leitch et al. 1996) and various species of knapweed (*Centaurea diffusa, C. maculosa*, and *Acroptilon repens*) (Hirsch and Leitch 1996).

Yellow starthistle (*Centaurea solstitialis* L., hereafter YST), a Eurasian native believed to have been introduced in the mid 19$^{th}$ century in imported contaminated alfalfa seed (DiTomaso and Gerlach 2000), is the most widely distributed non-crop weed in California (DiTomaso et al. 2000). It may now be found in much of the U.S., although by far the heaviest infestations, in addition to California, are in other western states including Idaho, Oregon and Washington (USDA 2006; USGS 2005). Surveys of county agricultural commissioners reveal that the area in California infested by YST has increased significantly over the past five decades, from 1.2 million acres in 1958 to 1.9 million acres in 1965, 7.9 million acres in 1985, and 14.3 million acres in 2002 (Maddox and Mayfield 1985; Pitcairn et al. 2004).

YST spreads via spectacular levels of seed production, with dispersion aided by birds and, more commonly, human activities such as road building, construction, and the movement of contaminated vehicles, equipment and horticultural soils. Each plant is capable of producing up to 100,000 seeds (DiTomaso 2006) of which approximately 95% are viable (Lass et al. 1999). Some seeds remain productive for as long as ten years, posing significant challenges to YST control and/or eradication efforts.

This paper reports the results of a survey designed to collect primary data from ranchers in California regarding the economic effects of YST. The survey data comprise direct reports of production losses, out-of-pocket YST management costs, and other factors for California ranchers. Additionally, we combine the direct reports of the surveyed ranchers with county-level data on YST infestation and land use to estimate rancher losses and costs on a statewide basis for California.

## METHODS

### Survey Design and Administration

We designed and administered a non-random survey (the *California Yellow Starthistle Survey: Economic Impacts on Agriculture*) of ranchers in California counties with substantial cattle grazing activity. Prior to finalization, the survey was reviewed by specialists at the California Department of Food and Agriculture and the California Cattlemen's Association, and, after inclusion of their comments, was endorsed by both institutions. The process of survey administration began with pre-testing in spring 2003 and continued with full implementation through summer and early fall 2003.

Respondents were able to complete surveys either by mail or via the internet. To support implementation of the survey by mail, the California Cattlemen's Association provided lists of ranchers in the three counties of primary interest (Calaveras, Mariposa, and Tehama). Mail survey implementation then involved an attempted census of all cattle ranchers in those three counties. These counties were chosen because of the importance of livestock ranching and grazing to the agricultural economy of those counties, and the expressed interest of ranchers in the YST problem as evidenced by their attendance and comments at focus meetings. In addition, marketing information on how to participate in either version of the survey (hard copy or internet) was distributed to a number of stakeholder groups in counties with significant levels of YST and livestock ranching activity. This effort was undertaken in order to achieve a broader, more diverse spectrum of state-wide responses for comparison.

The survey gathered detailed information from ranchers on topics related to YST infestation and control. First, general information was collected with respect to grazing practices, number of animals grazed, basic ranch characteristics, and demographic attributes of the ranchers. Second, the survey posed many questions specific to YST infestation on each rancher's rented and owned lands, beginning with queries on both the number of acres infested and the average percent cover of YST on infested acres. Questions were also included to identify estimated forage production losses due to YST infestation, rancher out-of-pocket expenses for YST control, types of YST control strategies utilized, and other actions taken in response to YST infestation (e.g., purchasing additional feed for livestock or shifting livestock to another grazing area). Finally, the survey requested ranchers' opinions on recreation and wildlife impacts of YST and the potential for different weed management programs.

The survey contained separate modules for collecting data for private and public lands. However, since the majority of respondents managed private lands (294 respondents versus 33 for public land), the current focus is on YST impacts on private agricultural lands.

**Estimating Aggregate Economic Losses**

The survey results were combined with county-level data on forage production area (CASS 2001) to estimate aggregate economic losses and costs due to YST for Calaveras, Mariposa and Tehama counties, and also for the state of California as a whole. These calculations include only economic losses related to grazing land, thereby excluding other economic losses imposed by YST, such as those associated with increased water uptake by YST plants, damages to native plant habitat, and impaired outdoor recreation activities (e.g., hiking and trail riding). That is, the economic losses estimated below are limited strictly to reductions in grazing opportunities for domestic livestock and related weed control expenses.

Aggregate losses in ranchers' net revenues due to YST were developed as follows. First, the survey data allowed for the estimation of the mean YST-induced reduction in net revenue per acre from livestock operations. Second, data on the total production area of rangeland and pastureland, by county, are available from the California Agricultural Statistics Service (CASS 2001). Combining these data allowed for the estimation of annual losses in net grazing revenues due to YST in the three focus counties as:

$$L_i = Y^{nr} \eta^{nr} A_i^{nr} + Y^{ip} \eta^{ip} A_i^{ip} \qquad (1)$$

where $L_i$ = annual loss in net revenues from grazing in county *i*, in dollars per year;

$Y^{nr}$ = baseline net revenue on native range in the absence of YST and other weeds, in dollars per acre per year;

$\eta^{nr}$ = reduction in forage (grazing) yield caused by YST on native range, as a proportion of total yield;

$A_i^{nr}$ = harvested area of ‘pasture, range’ in county *i*, in acres[1];

$Y^{ip}$ = baseline net revenue on improved pasture in the absence of YST and other weeds, in dollars per acre per year;

$\eta^{ip}$ = reduction in forage (grazing) yield caused by YST on improved pasture, as a proportion of total yield; and

$A_i^{ip}$ = harvested area of ‘pasture, irrigated’ land in county *i*, in acres.

Losses in grazing net revenues for Calaveras, Mariposa and Tehama counties were computed using survey data and Equation (1), because the survey provides the best available picture to date of YST infestation rates and yield losses as they are estimates provided by the ranchers themselves. Baseline net grazing revenue ($Y^{nr}$ and $Y^{ip}$) and reduction in forage yield due to YST ($\eta^{nr}$ and $\eta^{ip}$) were calculated from both individual target counties and aggregated survey data to confirm the appropriateness of using the aggregated data for this analysis.

While the survey collected information on individual experiences in non-target counties, the area represented by respondents from those counties was insufficient to give a clear picture of the YST infestation rates state-wide. Therefore, to extrapolate to all of California, we integrated the survey and county grazing acreage data with estimates of the extent of YST infestation throughout the state.

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[1] $A_i^{nr}$ and $A_i^{ip}$ come from CASS (2001). Since the CASS data separates grazing land into range and irrigated components, we used irrigated area as a proxy for improved pasture. This underestimates the losses on improved pasture and on irrigated pasture for two reasons. The losses on improved pasture are underestimated because much of the actual improved pasture area is likely included in the CASS “pasture, range” area, which in this analysis has the lowest grazing value ($6.11/acre). The losses on irrigated land are underestimated because the value from the survey for improved land is $16.75/acre, while the reported value from CASS (2001) for irrigated pasture averages $96.60/acre. Losses specific to irrigated pasture were not calculated in the survey because YST infestation is not as significant an issue as on native range and unirrigated pasture.

In this case, average losses in grazing net revenues due to YST on a state-wide basis were calculated from the survey results for both native range and improved pasture. Estimates of YST infestation area by county were drawn from Pitcairn et al. (2004), based on information reported by California county agricultural commissioners and their staff. The proportion of YST infested area that has historically been used as grazing land was estimated through administration of a second survey during 2004 – the *Short Survey on Yellow Starthistle and Grazing Lands in California.* This survey collected information from County Extension agents and land management professionals in twenty-three California counties, targeting those with the largest YST infestations and the largest amounts of rangeland. The survey asked each respondent to estimate the fraction of YST-infested area in their county that has historically been used as grazing land, as opposed to forestland or steep terrain unsuitable for grazing. Since uncertainty is involved in estimating this proportion, the survey allowed respondents to indicate ranges of percentages (0-10%, 11-20%, etc.) in which they believe the true proportion lies. While it would be preferable to have more exact estimates (e.g., from satellite imaging or GPS data), such data are currently not available.

Data for the state-wide analysis was thus collected from four sources: the *California Yellow Starthistle Survey: Economic Impacts on Agriculture* (hereafter the *Long Survey*), the *Short Survey on Yellow Starthistle and Grazing Lands in California (Short Survey)*, grazing production area from the California Agricultural Statistics Service (CASS 2001), and YST infestation area from Pitcairn et al. (2004). Annual losses in net grazing revenues due to YST were estimated by California counties as follows, and then summed for the state as a whole:

$$L_i = (g^{nr} A_i^{nr} + g^{ip} A_i^{ip})\, \delta_i W_i \qquad (2)$$

where: $L_i$ = annual loss in net revenues from grazing in county *i*, in dollars per year;

$g^{nr}$ = mean losses in grazing net revenues due to YST on native range (estimated from *Long Survey* results), in dollars per acre per year;

$g^{ip}$ = mean losses in grazing net revenues due to YST on improved pasture (estimated from the *Long Survey* results), in dollars per acre per year;

$\delta_i$ = amount of YST-infested land in county *i* historically used for grazing (estimated from the *Short Survey* results), as a proportion; and

$W_i$ = area in county *i* that is estimated to be infested with YST (from Pitcairn et al. 2004), in acres.

All other variables are as previously defined.

Next, we extrapolated the results of the survey to estimate the amount of money that ranchers are spending out of their own pockets to control YST. This is estimated for both the target counties and the entire state as:

$$e_i = c(A_i^{nr} + A_i^{ip}) \qquad (3)$$

where $e_i$ = out-of-pocket expenditures by ranchers to control YST in county *i*, in dollars per year;

c = mean out-of-pocket expenditures by ranchers to control YST (state-wide estimate from *Long Survey* results), in dollars per acre per year; and

$A_i^{nr}$ and $A_i^{ip}$ are as previously defined.

Note that the rancher expenditures in Equation (3) include only explicit outlays of money and thereby exclude ranchers' cost of time spent managing YST, a potentially significant cost.

Extrapolation to the state level of both the annual losses in grazing revenue and out-of-pocket YST control expenses involves only 49 out of the 58 total California counties. This is because nine counties – Alpine, Del Norte, Imperial, Inyo, Mono, Orange, San Bernardino, San Diego, and San Francisco – satisfy one or more of the following conditions: 1) no current infestations of YST, 2) extremely small YST infestations at present, or 3) lack of data on the acreage of grazed rangeland or pastureland. The estimation of impacts for the remaining 49 counties represents an analysis that pertains to those regions where YST invasion is a *bona fide* issue for livestock grazing operations.

## RESULTS

Since survey effort was concentrated in Calaveras, Mariposa and Tehama counties, these counties comprised 71% of the responses. In addition, ranchers in 30 other California counties completed and returned surveys, yielding a total of 302 surveys returned, 243 in hard copy and 59 from the internet-based version.[2]

### Key Survey Findings

The first component of the survey collected basic information about the ranching operation. Seventy-one percent of survey respondents graze cattle on rangeland or forestland, while 48% graze cattle on pastureland (Table 1). About 13% of the ranchers grow alfalfa or meadow hay for their own use. Most of these ranches lie at relatively low elevations, with more than 57% of operations below 1,500 ft elevation and 81% of operations below 2,500 ft elevation. Of those respondents reporting management of

[2] When pasture land managed by survey respondents was compared with CASS (2001) harvested pasture (range plus improved), we found that the survey covered approximately 42%, 10% and 25% of the pasture in Calaveras, Mariposa and Tehama counties, respectively.

private land, the average land area was 1,296 acres and 2,667 acres per respondent, for owned and leased land, respectively (Table 2). By and large the ranchers manage mostly unirrigated land for both owned and leased private property, with the average respondent reporting that only about 15% of their land is irrigated (n=264).

Next, the survey focused on the incidence of YST. Of the 294 respondents who manage private lands, 93% reported that there currently is, or at some point had been, YST on their land. (Unless otherwise noted, the statistics reported henceforth are for privately managed lands.) While 18% of respondents were unsure about the timing of YST appearance on their land, 63% of those who did know indicated that the weed had first appeared after 1970 (see Figure 1). When asked to estimate YST cover (YST as a proportion of total vegetation), the majority of respondents (62% in 2000, 64% in 2003) indicated YST cover on infested land area to be less than 30% ( see Figure 2), with no consistent or identifiable shift in cover categories between 2000 and 2003.

Detailed results were obtained regarding baseline forage productivity and ranchers' estimates of YST impact on forage yields (Table 3). Estimated pasture yield decrease due to YST varied between respondents from minimal to >50%, with mean losses of 15.3% and 12.7% on native range and improved pasture, respectively. On native rangeland where the mean net revenue on grazing land not infested with YST (baseline net revenue) was approximately \$6 $ac^{-1}$ $yr^{-1}$, the estimated mean drop in net revenue due to YST infestation approached \$1 $ac^{-1}$ $yr^{-1}$. Because of higher baseline forage productivity on improved pasture (\$16.75 $acre^{-1}$ $yr^{-1}$), absolute dollar losses per acre were more than double that of native range. For target counties, the county-specific calculations of baseline net revenue and estimated yield losses due to YST were similar to survey-aggregate results, but survey-aggregate results were utilized for all calculations.

In addition to the indirect costs of forage yield losses, other costs related to YST infestation that were incurred by ranchers were significant. These included effort expended to compensate for decreased forage yield, such as purchasing additional hay, leasing additional grazing land (public and private), or selling livestock (Table 4). Even though we did not attempt to estimate quantitatively the costs associated with these changes, it is clear that many ranchers are incurring such adjustment costs. More than half (total of 55%) of respondents reacted to YST-induced forage losses by selling animals and/or purchasing additional forage, with these responses much more likely ($p<0.001$) from ranchers who reported higher yield losses. The most common response to YST was to take action to control weeds, and almost 60% of these respondents reported using chemical applications (Table 5), most often Roundup (glyphosate) and Transline (clopyralid). Mowing and timed grazing were also common practices for weed control, with other methods such as biological control, burning, and cultivation also utilized.

Direct costs incurred by ranchers for YST control (exclusive of compensation for decreased forage yield and rancher's labor) were reported in the survey as out-of-pocket expenses. Among the 168 ranchers who reported monetary expenditures on YST management, the mean reported annual expenditure was $1,247. This was significantly greater than the $374 spent on YST control that originated from other sources (federal and state government support).

## Estimates of Aggregate Economic Losses from YST

Calculations of forage losses and rancher expenditures in Calaveras, Mariposa and Tehama counties (total for all three counties) are shown in Table 6[3]. Losses due to reduced forage for livestock were estimated at $1.7 million or $1.0 million, using Equations (1) and (2), respectively. The true value is most likely closer to the higher estimate due to the larger number of respondents (answers from > 200 respondents/ ranchers used for Eq (1) versus estimates from a smaller number of professionals contributing to one of the parameters in Eq (2)), and the fact that the ranchers work more closely with the land in question. However, the similarity of the tri-county estimates derived from the two equations provides positive validation of our use of Eq (2) to develop statewide loss estimates. Out-of-pocket rancher expenditures on YST control in Tehama, Calaveras, and Mariposa Counties are estimated to be about $1 million annually and are thus of the same order of magnitude as the estimated losses due to reduced forage availability.

We now turn to estimates of the statewide forage losses and rancher costs (Table 7). The central estimate of statewide YST-caused losses due solely to reduced forage for livestock is $7.96 million per year. The central estimate of statewide rancher out-of-pocket costs for YST control (*excluding* time cost of labor) is $9.45 million annually. The sum of these estimates is $17.41 million/yr. "Lower" and "Higher" estimates of both

[3] Since two of the target counties, Tehama and Calaveras, had sufficient responses to calculate dependable county-specific values of mean grazing revenue and grazing yield losses due to YST, these county-specific values were compared to the survey aggregate values and total losses calculated. Forage losses were calculated at $367,000 (Calaveras) and $916,000 (Tehama) using survey-aggregate values and $289,000 (Calaveras) and $1,062,000 (Tehama) using county-specific data. The similar range of results confirms the appropriateness of using survey-aggregate data for these counties and the rest of the state.

forage losses and out-of-pocket control costs are derived using the 95% confidence intervals (i.e., plus/minus 2 standard errors) for the estimates of several key parameters in the equations: mean net grazing revenues per acre in the absence of YST, mean decrease in forage yield attributable to YST, and mean YST control expenditures per acre by ranchers. The resulting Lower and Higher estimates encompass a range that runs from $10.87 million/yr to $24.26 million/yr. The central estimate of losses plus costs induced by YST on grazing lands ($17.41 million) amounts to 6.4% of the total harvested pasture grazing value for the state of California ($272 million in 2001).

## DISCUSSION

Survey results indicated reductions in productivity on infested native range and improved pasture of 15.3% and 12.8%, respectively. This is much lower than the >80% reduction in productivity due to YST on Idaho rangeland assumed by Hartmans et al. (1997), which was based on one expert's opinion. However, our survey results are more comparable to the results of more recent research on the best professional judgments of weed scientists, county farm advisors, public land managers and other specialists familiar with YST and its spread in California specifically (Eiswerth and van Kooten, 2002). For example, that study found that experts predicted forage losses in the range of 6-10% for minimal infestations and 22-28% for moderate infestations, with moderate infestation defined by most experts to be around 30% cover. Since the majority of the ranchers in our survey indicated that YST cover on their infested lands was less than 30%, their self-reports of estimated forage losses in the range of 10-15% (on average) do not appear out of line with the best judgments of weed scientists and land managers as reported in Eiswerth and van Kooten. Still, the estimates provided in this paper are subject to potential survey error, with some respondents perhaps reporting reductions in productivity based on all private pastureland and not only on the area currently infested with YST (which would thereby lead to underestimates of YST grazing losses). In the final analysis, in deriving our estimates we have assumed that agricultural producers are able to assess productivity losses with some accuracy. While this likely is true of many respondents to the survey, and average estimates of losses across the sample may be quite realistic, it should be recognized that the values derived here are dependent on the experience and best estimates of the ranchers contributing to the survey.

The economic value of grazing land from the survey results is also somewhat lower than the average value reported by the CASS (2001). For example, where our survey found the average net revenue for native rangeland to be \$6.11/ac, the CASS statewide average value for rangeland was \$9.32/ac. This is another factor pointing to a probable underestimation in this paper of losses due to YST infestation.

Total costs to grazing agriculture due to YST (forage loss plus control costs) in the three focus counties (Calaveras, Mariposa and Tehama) range between 7% and 16% of the total pasture revenue in these three counties (depending on the equation used), while totaling at least 6.4% of total pasture revenue statewide. Because of the greater prevalence and damage in the target counties (most notably Tehama County where survey respondents indicated that 42% of private grazing land was infested), control efforts would have the most economic impact on ranching in these regions. Since the 'statewide' estimates exclude 9 of 58 California counties that are unlikely to exhibit large rangeland damages due to YST infestation, such estimates might increase slightly if impacts in these counties were included, especially as YST continues to spread.

Therefore, while this paper's estimates of losses and costs are the most complete possible with the currently available data, they should be considered lower-bound estimates of true damages. Further, they are limited only to grazing-based agriculture and do not include the monetary cost of time that ranchers spend controlling YST, which likely is substantial.

Pimentel et al. (2000) calculated total US annual costs due to invasive weeds in pasture to be approximately $6.0 billion, with the majority (83%) of the costs a result of control efforts (as opposed to actual losses and damages). In our analysis of YST in California on private land, costs due to weed control efforts for the three target counties were approximately 36% to 49% of total annual losses/costs of $2.0 to $2.7 million. In the statewide calculations, 54% of the total annual costs of $17.4 million were related to control costs rather than losses and damages. If control costs incurred by public agencies and damages experienced by other sectors were included, the ratios of losses and damages versus control costs could also be impacted.

While a significant impact on the grazing sector of California agriculture, our estimates of annual livestock forage losses and rancher out-of-pocket costs are not substantial in view of the $26 billion contributed annually by the State's agricultural sector. The absolute cost of YST may also seem less than one might expect given the pervasiveness of the weed in California. In light of our findings, it is important to note two factors. First, YST tends to invade and occupy ecological niches that typically offer relatively low per-acre values in agriculture, namely, semiarid grasslands. Therefore, though the relative impacts on those individual ranchers affected by YST are large, the aggregate monetary losses (e.g., due to reduced forage) may be lower than those yielded by other types of nonnative weeds invading more productive agricultural lands. Second, it is important to remember that our analysis focuses only on livestock forage losses and rancher out-of-pocket expenditures.

The monetary values of other negative impacts of YST are likely to be greater than those examined here. For example, Gerlach (2004) provides a "rough preliminary estimate" indicating that the value of water lost to the Sacramento River watershed alone (due to higher rates of plant water uptake by YST relative to other vegetation) may range in the tens of millions of dollars annually. The monetary values of a suite of other ecological impacts (increased soil erosion, runoff of nutrients, losses in biodiversity, etc.), as well as depressed recreational activities (e.g., hiking, hunting), may also be substantial. However, these have not been documented for YST.

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**Table 1. Selected statistics from the *California Yellow Starthistle Survey: Economic Impacts on Agriculture.***

| Ranch Characteristics | % of Respondents[1] |
|---|---|
| Maximum elevation < 1 500 ft | 57.7% (n=279) |
| Maximum elevation < 2 500 ft | 81.0% (n=279) |
| | |
| Cattle grazing on range or forest land | 70.8% (n=298) |
| Cattle grazing on pastureland | 48.3% (n=298) |
| Other grazing stock | 57.0% (n=298) |
| | |
| Grow crops (other than pasture) | 29.9% (n=284) |
| Alfalfa/meadow hay for own use | 13.0% (n=284) |
| | |
| Own private land | 95.0% (n=298) |
| Lease private land | 39.5% (n=296) |

[1]In this column, n denotes the number of survey respondents who answered the question.

**Table 2. Land area managed by survey respondents.**

| Type of land | Number of respondents | Mean area per respondent, acres (std error in brackets) |
|---|---|---|
| Private land – owned | 283 | 1,296 (175) |
| Private land – leased | 117 | 2,667 (627) |
| Public land – leased | 31 | 14,820 (3,726) |

**Table 3. Baseline grazing productivity and impacts of YST, std errors in brackets.**

| Characteristic/parameter | Type of grazing land | |
|---|---|---|
| | Native range | Improved pasture |
| Mean net revenue of grazing land not infested with YST or other invasive weeds | \$6.11 $ac^{-1}yr^{-1}$ (\$0.38) | \$16.75 $ac^{-1}yr^{-1}$ (\$1.75) |
| Mean decrease in forage yield attributable to YST | 15.3% (1.0%) | 12.8% (1.4%) |
| Mean decrease in net revenue attributable to YST | \$0.93 $ac^{-1}yr^{-1}$ | \$2.14 $ac^{-1}yr^{-1}$ |

**Table 4. Actions taken by ranchers in response to YST-related forage losses on private land (n=246).**

| Action | % of Respondents |
|---|---|
| Purchase additional hay for feeding | 46.8% |
| Increase public grazing allotment | 0.0% |
| Lease additional private land for grazing | 12.2% |
| Sell livestock to reduce herd size | 21.5% |
| Take action to control weeds | 83.3% |

**Table 5. Actions taken by ranchers to control YST on private land (n=198).**

| Action | % of Respondents |
|---|---|
| Chemical application | 59.6% |
| *Roundup (glyphosate)* | *32.3%* |
| *Transline (clopyralid)* | *23.7%* |
| Mowing | 46.5% |
| Timed grazing | 34.9% |
| Cultivation | 20.2% |
| Prescribed burning | 19.2% |
| Biological Control | 16.2% |

**Table 6. YST annual loss and cost estimates for Calaveras, Mariposa, and Tehama counties added together (2003).[1]**

| Category of loss/cost | Estimated YST Losses and Costs, 2003 |
|---|---|
| Losses due to reduced forage for livestock | |
| As per Equation (1) | \$1.72 million |
| As per Equation (2) | \$1.00 million |
| Rancher out-of-pocket expenditures for YST control (*excluding* time cost of labor) | \$0.98 million |
| Subtotal losses/costs | \$1.98 to \$2.70 million $yr^{-1}$ |

[1]The estimates of lost forage in this table are based in part on extrapolations using data for harvested pasture acreage by county. Since the number of acres of pasture that would be harvested if YST did not exist is not observable, but presumably higher than current harvest, the estimates of losses are biased downward. For this and other reasons the estimates presented in this table should be considered lower-bound estimates of the true impacts of YST in these three counties. In addition, the estimated 'subtotal' losses and costs only include the loss/cost components included in the table and exclude other lost economic values (e.g., water losses, losses in outdoor recreation activity, lost ecosystem service flows such as soil retention, nutrient cycling, biodiversity, etc.), public expenditures on YST management, and several components of private expenditure on YST control.

**Table 7. California YST annual loss and cost estimates (Year 2003).**[1]

| Category of loss/cost | Estimated Annual YST Losses and Costs, 2003 | | |
|---|---|---|---|
| | Lower estimate | Central estimate | Higher estimate |
| Losses due to reduced forage for livestock | $5.92 million | $7.96 million | $10.31 million |
| Rancher out-of-pocket expenditures for YST control (*excluding* time cost of labor) | $4.95 million | $9.45 million | $13.95 million |
| Subtotal losses/costs statewide | $10.87 million (+) | $17.41 million (+) | $24.26 million (+) |

[1]The estimates in this table pertain to 49 of the 58 counties in California. As noted below Table 2, since the number of acres of pasture that would be harvested if YST did not exist is unobservable, but presumably higher than current harvest, the estimates of losses are biased downward. For this and other reasons the estimates presented in this table should be considered lower-bound of the true grazing-related impacts of YST in the state of California (hence the (+) notations in the last row of table). In addition, the estimated 'subtotal' losses and costs exclude many other categories of lost economic values and thus are not reflective of the comprehensive impacts of YST (see footnote to Table 6).

**Figure 1. Date of YST first appearance, on private land, as reported by survey respondents (n=271).**

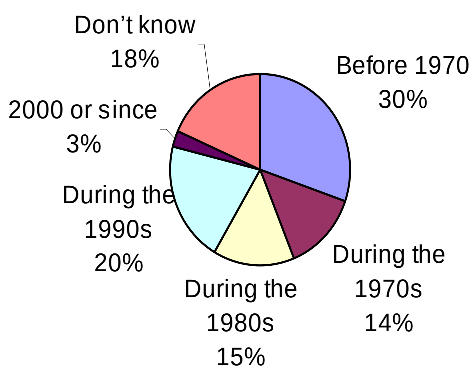

**Figure 2. Estimated ground area covered by YST, as a proportion of total vegetation, on infested private land (n=223 (2000) and 212 (2003)).**