Pest Management Grants Final Report

Contract 97-0249

Management of Riparian Woodlands for Control of Pierce's Disease in Coastal California

Principal Investigators: Alexander H. Purcell and Joe R. McBride
Department of Environmental Science,
Policy, and Management
University of California
Berkeley, CA 94720

March 31, 1999

Prepared for California Department of Pesticide Regulation

DISCLAIMER

The statements and conclusions in this report are those of the contractor and not necessarily those of the California Department of Pesticide Regulation. The mention of commercial products, their source, or their use in connection with material reported herein is not to be constructed as actual or implied endorsement of such products.

ACKNOWLEDGMENTS

This project received matching funds with a grant from the University of California IPM program and a grant from the American Vineyard Foundation. The latter agency provided matching funds to research funds raised by the grower sponsored Napa Valley Pierce's Disease Task Force, now renamed the North Coast Pierce's Disease Task Force. The principal investigators and most cooperators have attended regular meetings of the Task Force and have discussed progress on this and related research projects and answered questions from growers, other researchers, representatives of the Department of Fish and Game, and other government agencies. Important cooperators include:

Ed Weber, Farm Advisor, UCCE, Napa County
Rhonda Smith, Farm Advisor, UCCE, Sonoma County
Lucia Varela, Area IPM Specialist, UCCE
Fred Botti, Biologist, California Department of Fish and Game
Phill Blake, Napa Natural Resources Agency, USDA
Donald Dahlsten, ESPM, UC Berkeley

This report was submitted in fulfillment of DPR contract 97-0249, Management of Riparian Woodlands for Control of Pierce's Disease in Coastal California; Alexander H. Purcell and Joe R. McBride, Principal Investigators, Department of Environmental Science, Policy and management, University of California, Berkeley, CA 94720 under the partial sponsorship of the California Department of Pesticide Regulation. Work will be completed by March, 1999.

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

PAGE

APPENDIX 2: Figures

ABSTRACT

Pierce's disease of grape is caused by the bacterium *Xylella fastidiosa,* which is transmitted to grapevines by insect vectors. The blue-green sharpshooter (BGSS), the principal vector in coastal California, enters vineyards from adjacent riparian zones. This project showed that removing the principal breeding host plants of BGSS from riparian habitats and replacing them with native trees and shrubs substantially reduced populations and flight of BGSS. The reduction in the overwintering BGSS spring migration into vineyards was also significant. Sweep net sampling over a four year period documented California mugwort, Himalayan blackberry, California blackberry, wild grape, and elderberry as the most common major riparian breeding hosts of BGSS. Less common but highly attractive breeding plants were stinging nettle, California Brickellbush, Mexican tea, mulefat, cocklebur, and large periwinkle. Over a three year period (1996-98), control of these hosts on our two managed sites in Napa Valley reduced catches of BGSS on sticky traps from 70 to 99% in the plots where vegetation had been removed and replaced compared to adjacent undisturbed controls. UCCE, and an Internet site encouraged community involvement and support. A broad-based work group led by the California Department of Fish and Game was convened to develop environmentally sound methods of implementing vegetation management for the control of Pierce's disease.

EXECUTIVE SUMMARY

This is the final year of a multi-year project funded in part by DPR since 1996 to experimentally manage riparian vegetation to reduce Pierce's disease in adjacent vineyards while preserving or enhancing environmental attributes of riparian habitats. The objectives were to replace principal breeding plants of the principal Pierce's disease vector, the blue-green sharpshooter (BGSS) with native riparian trees and shrubs that do not support multiplication of BGSS. During three years, we established four replicate sites. A buffer planting of Douglas fir or redwood trees to reduce flights of BGSS from riparian habitats into vineyards were discontinued after two years because of the slow growth of the buffer plantings. We introduced new replicate sites annually, beginning with the first in 1996. We used yellow sticky traps attractive to BGSS to measure net activity in riparian zones in three sites in Napa and Sonoma Valleys. In the late summer we collected adult BGSS from study sites and assessed their natural infectivity by testing their ability to transmit to grape test plants in the laboratory. Our study results indicated that removal and continued exclusion of five species of plants along riparian corridors and planting suitable openings with native trees and shrubs can reduce populations of BGSS significantly during the spring migration of overwintering adults and the early summer migration of new adults into adjacent vineyards. At one site a few other plant species were found to harbor high densities of immature BGSS. The spring movements of BGSS into vineyards appears to be the most important for establishing infections of *X. fastidiosa* that develop into chronic Pierce's disease, so reductions during April-May are considered to be of the greatest impact on disease spread. The reductions achieved surpass previous levels of control obtained with insecticidal treatments of riparian habitats and should be more sustainable over future years.

In 1998 we completed the last of four annual sweep net surveys during the breeding season (April to mid-July) of the BGSS to identify or confirm host plant preferences of BGSS and the suitability of native species for vegetation management. Our surveys were always conducted in riparian zones adjacent to vineyards. The five species that were the most common preferred breeding hosts were Himalayan and California blackberry, wild grape, elderberry, and mugwort. The former three species also support systemic movement of the Pierce's disease bacterium. California Brickellbush, Mexican tea, mulefat, stinging nettle, and cocklebur were less common breeding hosts. Large periwinkle is a minor breeding host that can be significant when it forms extensive carpets within riparian zones. Both chemical and mechanical weed control practices were used to continue exclusion of breeding hosts and to promote growth of planted and existing native tree and shrubs. Native shrubs such as snowberry, wild rose, spice bush, and native tree stump sprouts or willows were minor breeding hosts when growing within mosaics of major hosts but not as isolated plants within the developing understory on managed sites.

We established the first experimental site for the demonstration of vegetation management along Conn Creek in Napa County in 1996, following our monitoring of BGSS populations in 1995. The unexpectedly slow growth of conifer buffers in a riparian levee environment led us to discontinue buffer strip studies begun in 1996, although we continued to monitor BGSS activity in these sites. In 1997 we added a new site that had been monitored in 1996, along the Napa River near Yountville. We selectively cleared vegetation throughout the summer along a 2000 foot-long plot for planting in 1998, contiguous with an undisturbed control. A third new site, along Maacama Creek in Sonoma County also monitored since 1996, was added to the project for 1998 with equal 1,100-foot managed and control plots. The selective plant removal on this third site was begun but not completed during the winter and spring of 1998 due to continued rain and creek flooding. We planted eleven species of hardwood seedlings to replace plant removals. The Maacama Creek site could not be completed in 1998 until March 1999, so results from this site will not be completed until fall of 1999.

Over the past three years (1996-98) on the Conn Creek site, we observed encouraging results with the selective riparian host plant removal and native replanting treatment. Sticky trap catches of BGSS were reduced 95% in 1996, 97% in 1997, and 99% in 1998 on the managed plot compared to the undisturbed control. The Napa River site in 1997 had selective host removal in 1997 but no replanting resulting in a 72% reduction in BGSS trapped versus the control plot. In 1998 after planting and continued weed control the reduction was similarly 68% with both years reflecting the influence of one trap on the managed plot that accounted for 95% of the treatment's seasonal BGSS trap count each year. The partial clearing in and replanting on the Maacama Creek plot reduced the spring peak trap by 80% in 1998 on the managed plot compared to the control plot but an accurate measure of vegetation management will not be available until the 1999 season now that selective plant removal and replanting is completed. The partial removal and replanting of vineyards near our experimental sites in some years prevented some direct comparisons of BGSS activity in vineyards adjacent to riparian corridor managed and control sites.

To monitor levels of infectivity of BGSS with *X. fastidiosa*, we collected adult BGSS from the two Napa County and the Maacama Creek sites every August-September. We returned the insects to the lab and confined them singly (20 per site) or in groups of 5 (100 per site) to test them for their ability to transmit *X. fastidiosa* to test grape vines. Single insect tests gave the most accurate estimates for high transmission rates (>40%), and group tests gave the best estimates of low transmission rates (<20%). Each year, we were able to collect only a few BGSS in the vegetation removal/replacement plots, another indication of how strongly vegetation removal reduced populations of BGSS. From 1996 through 1998 the estimated rates of transmitting BGSS ranged from 10 to 50% (1996), 10 to 30% (1997), and 5 to 15% (1998). These estimates of natural infectivity of BGSS with *X. fastidiosa* should provide useful epidemiological data, but will not provide data on the effects of vegetation management on natural infectivity because we could not collect adequate numbers of BGSS from the treated plots.

INTRODUCTION

Pierce's disease (PD) of grape is an important lethal disease of grapevines that has caused much damage in unpredictable epidemic cycles (Hewitt, Frazier et al. 1949). In 1997, PD caused at least $33 million losses in Napa and Sonoma counties (unpublished survey report of North Coast Pierce's Disease Task Force). PD is caused by the bacterium *Xylella fastidiosa* (Davis, Purcell et al. 1978), which is transmitted to grapevines by insect vectors. The blue-green sharpshooter (BGSS), the principal vector in the coastal valleys of California, enters vineyards from adjacent riparian zones (Hewitt, Frazier et al. 1949) (Goodwin and Purcell 1992). The early spring is considered to be the most important time for bacterial infections to become established in grapevines because late season infections do not often survive through the following winter (Purcell 1981). The blue-green sharpshooter has a single generation per year, overwintering as adults that can re-enter vineyards in the spring (Purcell 1975) (Hewitt, Frazier et al. 1949) (Severin 1949). Control of PD is directed against preventing infective vectors from entering vineyards, often using a systemic insecticide (dimethoate) on riparian vegetation in spring when BGSS has begun to fly but not yet entered vineyards (Goodwin and Purcell 1992).

BGSS has a wide plant host range (Severin 1949) (Purcell 1976), but host plant condition, mainly succulence of growth, is an important feature in making plants attractive for the feeding of BGSS (Purcell 1976). The number of breeding hosts, on which BGSS will lay eggs, is much smaller than the number of plants on which BGSS will feed at some time of the year. The plant preferences of BGSS change continually throughout the year (Purcell 1976). Wild grape, Himalayan blackberry, California blackberry, mugwort, willows, stinging nettle, and elderberries are the most common breeding hosts for BGSS (Severin 1949) (Purcell 1976) in the Napa Valley, but additional data was needed to further assess host plant preferences for feeding (primarily by adults) and breeding (as reflected in nymphal occurrence).

The possibility of manipulating the vegetation along northern coastal streams to reduce populations of the principle Pierce's disease vector, the blue-green sharpshooter (BGSS), became apparent during studies of Pierce's disease in two widely separated sites in Santa Cruz Mountain vineyards partially bordered by conifer and hardwood woodlands (our unpublished data). Populations of BGSS when measured by both sticky trap locations and sweep net sampling on native and host plants along and within the vineyard borders were consistently low or absent in the shaded understory compared to tree canopy openings dominated by host plants that were attractive for egg-laying by BGSS. The narrowness of and canopy gaps of many riparian zones near vineyards permit sufficient sunlight to support the succulent growth of understory plants and wild grape that are attractive hosts for the annual breeding of BGSS. In many cases, invasive weed growth hampers the growth and development of native riparian plant species and reduces plant and animal biodiversity. We reasoned that a mature riparian woodland with sufficiently dense canopy shade would be unattractive for BGSS except along edges where host plants could become invasive and attract BGSS.

These observations led us to propose a test of removing a relatively small number of riparian species, some of the most common of which are aggressively invasive exotic species, as a method of reducing populations of BGSS in riparian habitats during their breeding season (April to June). These months correspond to the time of year most critical for establishing infections of *X. fastidiosa* that will lead to chronic Pierce's disease. Later infections usually do not establish within vines sufficiently to survive the subsequent winter (Purcell 1981) (Purcell 1989). Our first goal was to reduce populations of BGSS by replacing plants such as wild grape, blackberry, and others used by BGSS for breeding with plants that are not favored by the BGSS for reproduction or feeding and should develop into a mature riparian woodland. Our second goal was to evaluate whether this management method reduced the percentage of BGSS that are infective with the Pierce's disease bacterium (*Xylella fastidiosa*).

METHODS

Vegetation Management.

We removed BGSS breeding hosts in riparian zones by mechanical methods and herbicides. The mechanical methods included power tools, hoes, and hand blades. We applied herbicides to new sprouts from old root systems, rhizomes, or seed. The mechanical weed clearing usually started in early summer and was completed by late winter in conjunction with plot scattered debris chips or burn piles. Glyophosate (Roundup® and Rodeo®, Monsanto Corp.) herbicide was typically applied late in the fall and prior to planting native species in the late winter or early spring when justified by sufficient new host shoot growth or periodic invasive weed growth in the managed plot.

The first site used for vegetation management was Conn Creek in Napa Valley where on the northern 2,100-foot section we established three same-sized plots consisting of an undisturbed control, a selective removal of vegetation to be replanted with eleven native trees (2,000 total), and a planted Douglas fir (1,150 total) buffer between the riparian corridor and the vineyard. On a contiguous 1,100-foot section of the corridor two plots consisting of an undisturbed control and a planted Douglas fir (1,000 total) and redwood (250 total) buffer were established. Conifer buffers were evaluated for their ability to grow into a barrier to BGSS migration into vineyards and eventually cast a dense shade on the host plant habitat that will reduce breeding habitat in the riparian zone. On the northern section virtually all of the understory was Himalayan blackberry with some overlain wild grape that also grew into fifteen 55+ year old decaying willows established during stream impoundment. The outside border of the three sections differed by the number of willow saplings, wild rose and the annual weed mixture during the growing season. Willows not associated intimately with the stream habitat were considered replaceable by suitable native trees. The 1995-96 host and willow cleared plot resulted in an east bank with a 700 x 75 foot clearing shaded by eight scattered oaks and walnut on the northern 150 foot length. The 55 foot wide west bank had sixteen larger oaks and walnut causing heavy shade where clustered and left no clearing unaffected by shade because some were scattered trees. The only host and weed removal done on the buffer plot was along the outside border of the riparian zone.

In 1997 we added a new site that had been monitored in 1996, along the Napa River near Yountville. We selectively cleared vegetation throughout the summer along a 2,000-foot plot, contiguous with an undisturbed control. The vegetation management was south of the control and had the same levee construction covered with numerous mature oaks, walnuts, eucalyptus, arundo cane, and willows and several patches of bolder rip rap to repair levee breaks. The poor canopy health of the willows and the age of many of the other trees permitted sufficient light for an understory of Himalayan blackberry, elderberry, periwinkle, and mugwort. Wild grape was prostrate on the levee bolder patches and blackberry and grew into the trees. These plants were scarce on the levee slopes and were concentrated on the levee bottom and remnant flood plain and then mainly on the west bank that had a 50 to 60 foot wide flood plain whereas the east bank had a paved road on top of the levee. Willows on the flood plain and levee banks were removed along with host plants but not the eucalyptus or four large arundo cane patches. Only plantings on the outside edges of the riparian zone would receive full sun exposure

A third new site, along Maacama Creek in Sonoma County also monitored since 1996, was added to the project for 1998 with equal 1100 foot managed and control plots. The selective plant removal on this third site was begun on the remnant flood plain but not completed on the upper or lower stream banks during the winter and spring of 1998 due to continued rain and creek flooding. A carpet of periwinkle and mugwort with large patches and scattered Himalayan blackberry and California blackberry dominated shrub layer on the flood plain with elderberry and wild grape growing both prostrate and into the canopy. The upper and lower stream banks contained all these hosts but were dominated by Himalayan blackberry and prostrate wild grape to the stream edge. Host and flood plain willow clearing and thinning of dense native tree patches resulted in very few locations not shaded during a good portion of the day.

Most tree seedling planting on all sites or buffer followed the same protocol. Native seed collections appropriately handled were sown in a bare root tree nursery and harvested for planting in the winter before the plot was to be planted. Planting of the natives in suitably moist soils in phase with the warming site was into power augured holes 4 diameter x 18-22 inches deep and 4 to 6 feet apart and 12 feet from the nearest large residual tree. This planting technique promotes rapid root growth to depth and development of a flood and wind stable root architecture when not combined by shoot promoting irrigation or growth tubes. California bay, live oak, and buckeye were planted on the outside edge where their eventual height will not shade cultivated grape. Live oak, walnut, big leaf maple, Oregon ash, and box elder were planted to the mid-slope of the stream bank with the first two concentrated on the outside and the latter two on the inside with the maple scattered throughout. Fremont cottonwood and white alder were planted on the low stream bank. No willows were planted since they were always in sufficient quantity along the stream edge. Two chemical and mechanical weed control treatments were needed on each site during the growing season.

This planting protocol was different in spring of 1999 when the Maacama Creek site was completed and replacements were planted on the Napa River plot due to a levee break and on Conn Creek because of flood damage. On all three sites the bare root that could not be planted due to heavy rains in 1998 were preserved in containers but were partially bare rooted prior to planting in the usual augured hole. No native shrub establishment was done initially on any plot so that they would not compete with the tree seedlings and their uncertain host status until July 1997 enough survey data accumulated. In 1998 and 1999 the Conn Creek and Napa River managed plots had snowberry, spice bush, and wild rose planted in spots where mature trees or planted trees cast shade over most of the day. Due to the abundant shade on the Maacama Creek plot it was possible with careful host removal to preserve spots of all three shrubs and adjust tree planting suitably.

Monitoring of the blue-green sharpshooter (BGSS).

Monitoring flight activity of BGSS adults. We used yellow sticky traps (Seabright Enterprises, Emeryville, CA) attached about 4 feet high on stakes at the edge of the riparian zone of each plot to monitor the flight activity of BGSS. We placed 4 traps on each side of every plot in our study and monitored trap catches weekly during spring months and weekly or biweekly for the remainder of the season. We began monitoring in late March and ended monitoring in September.

Surveys of riparian habitats to identify breeding hosts of BGSS The sweep net survey for adult and nymph BGSS (25 sweeps per sample plant) during the egg laying in April-May and hatching season in June-July begun in 1995 in the northern coastal valleys continued each year through 1998. Twenty five to thirty one riparian locations, often adjacent to vineyards in Napa, Sonoma, and Mendocino County, were surveyed each year. The typical protocol was to establish the presence of an adult or nymph population on evident host plants and to survey other weeds and native plants for BGSS. The crude method of sweep net sampling required that unknown host status plant sampling be done carefully by avoiding those situations with host foliage growing within the plant or disturbance of a host plant below the plant to be swept.

Testing individual BGSS (or groups) for transmission to test grapevines.

In late August, but more often in September each year, we attempted to collect at least 100 adult BGSS from each plot for testing their natural infectivity with *X. fastidiosa*. We returned the insects to the lab and confined them singly (20 per site) or in groups of 5 (100 per site) to test them for their ability to transmit *X. fastidiosa* to test grape vines. Single insect tests gave the most accurate estimates for high transmission rates (>40%), and group tests gave the best estimates of low transmission rates (<20%). Test grapevines were held in a greenhouse at Berkeley for at least three months. Plants with distinctive symptoms of PD were rated as positive. We cultured from remaining plants (Hill and Purcell 1995) and rated as positive those that yielded cultured *X. fastidiosa*.

RESULTS AND DISCUSSION

Vegetation Management.

In general, the results during 1998 for clear and plant treatment at the Conn Creek site continued to meet our expectations for the project. Data on the growth of new hardwood seedlings at the Conn Creek site is shown with the height growth of those seedlings planted in 1996 and the additional 200 of three species planted in 1998-99 (Figure 1**).** These data show that the 1996 hardwood transplants grew rapidly in areas without established trees but less under the competition of established trees. Survival of the 1996 planting of 2,000 seedlings is still above 80% due to resprouting after the extensive damage from three floods. The growth of the trees on the generally unshaded east bank has been so superior that they will have to be thinned with emphasis on the walnut that could come to dominate the site at the expense of diversity. Shrubs planted in 1998 are doing well and do seem adapted to growing non-invasively in the shade of saplings and mature trees.

The growth and survival of Douglas fir, planted as a buffer, has been disappointing. Poor growth of Douglas fir seedlings continued over the last year. Douglas fir growth was hampered by a dry spring in 1997, but even more by excessive competition from shading of established trees and competition with blackberries and annual weeds.

The second replication of vegetation removal and replacement with native tree seedlings was planted during March and April, 1998 along a 2,000 foot long section of the Napa River and a third replication was partially planted in April, 1998 along a 1,100 foot section of Maacamas Creek in Alexander Valley and was completed in march 1999 with both plot survivals above 85 % in February 1999. A total of 1,700 seedlings were planted on six foot spacing on the Napa River in 1998 and 200 replacements in 1999 and 1,250 were similarly planted on Maacama Creek followed in 1999 with the remaining 800 containerized seedlings now two years old. It appears that numerous residual mature oaks and walnuts in various states of vigor interspersed with the new seedlings visibly retarded growth in 1998 if not survival similar to the west Conn Creek three year data. Growth and survival of the last two replications will be measured in the spring of 1999. The major causes of mortality on the two managed sites was the extremely difficult to control weed growth due to late rains in 1998 and one flood event on each site followed by minor browsing by deer and rabbits. The Maacama Creek site currently has 80 native tree stump sprouts that can be managed to sapling status since the host removal and the preserved native shrub spots seem to be recovering from the single 1999 flood surge.

Activity of the blue-green sharpshooter (BGSS)

Monitoring flight activity of BGSS adults in managed and undisturbed plots. Vegetation management reduced sticky trap catches of BGSS in all managed plots for 1998 (Table 1), as we noted in previous reports for 1997 (Table 2) and 1996 (Figure 2, Table 3). Over a three-year period (1996-98) at our experimental site at Conn Creek, near Yountville, catches of BGSS on sticky traps

were reduced from 95 to 99% in the plot where vegetation had been removed and replaced compared to an adjacent undisturbed control. A second experimental site, along the Napa River near Yountville, that had been cleared in 1996 also had large reductions (more than 70%) in activity of the BGSS; catches at a single trap near adjacent undisturbed vegetation accounted for a majority of the BGSS activity that we detected in the vegetation management plot. All targeted vegetation at a third site was not removed in time to assess the effects of management on BGSS activity in 1998.

Figure 2 illustrates for 1996 how each side of the stream at managed or undisturbed plots at Conn Creek changed symmetrically over time. This symmetry also occurred at all other sites and other years (not shown). Reductions were as large or larger during the critical April-May period when infections of grapevines with *X. fastidiosa* are most likely to establish chronic infection.

Surveys of riparian habitats to identify breeding hosts of BGSS. To verify with multi-year data the breeding host preferences of BGSS, we repeated our sampling for nymphs each year of the study in a variety of habitats. Our surveys for BGSS nymphs, made during the spring months through early July, are summarized in Table 4 for 1998. The most common major breeding hosts are summarized in Table 5. The data for less common but highly attractive breeding hosts are summarized in Table 6. For comparison, data for "non-host" native trees and shrubs are summarized in Table 7. Low (<0.2) or zero BGSS catches on particular plant species were valuable as indicators that they were not significant breeding hosts of BGSS only when numerous such sweep net samples are taken during periods when BGSS nymphs could be collected from known breeding hosts at the same locale.

The number of sweep-net samples at any one location varied from year to year as a function of the BGSS population size. Fewer samples were needed in a location when the BGSS population was high. It is likely that we detected nymphs on some plant species because of the close proximity or contact with major breeding hosts below the sampled foliage. In 1997 and 1998 this problem was avoided by either sampling major and minor hosts first followed by natives separated by a suitable distance or sampling natives before extensive disturbance and sampling of host plants in the riparian zone. Willows that often grow in contact with major breeding hosts are especially difficult to sample in this manner, but enough isolated thickets and individuals were sampled during the breeding season to conclude that they and other natives are not breeding hosts but can be a food source when succulent shoots were available.

Our collections of adult and nymphal BGSS from perennial understory shrubs such as spice bush, wild rose, and snowberry may overestimate their status as potential breeding hosts for BGSS where these shrubs are intermixed with major breeding hosts of BGSS. Accumulating sweep net samples on isolated native shrubs in the riparian zone rarely results in any BGSS catches during the critical vineyard migration periods due to competition by a native tree cover. Only three riparian sites that we sampled had spice bush, snowberry, or wild rose patches under a native tree canopy during our 1997 and 1998 surveys. These shrub groups had BGSS counts similar to the local native trees in early summer but appeared to only function as food hosts since we did find nymphs on these plants.

These limited samples and observations on native shrubs are all from Sonoma County locations in Alexander Valley and along Dry Creek. Thus the potential of patches of native shrubs under a tree canopy to support breeding of BGSS remains somewhat unknown. It seems prudent to plant native shrubs as scattered individuals until more data can be collected on the managed vegetation units.

Testing individual BGSS (or groups) for transmission to test grapevines.
Each year, we were able to collect only a few BGSS in the vegetation removal/replacement plots, another indication of how strongly vegetation removal reduced populations of BGSS. From 1996 through 1998 the estimated rates of transmitting BGSS ranged from 4 to 48% (1996). Results by site and year are given in Table 8. These estimates of natural infectivity of BGSS with *X. fastidiosa* should provide useful epidemiological data, but will not provide data on the effects of vegetation management on natural infectivity because we did not collect adequate numbers of BGSS from the treated plots.

SUMMARY AND CONCLUSIONS

This project showed that:

1. Removing and subsequent control of those plants that serve as BGSS breeding hosts and replacing them with native trees and shrubs dramatically reduced BGSS abundance. Sticky traps and sweep net sampling used to monitor BGSS estimated the degree of reduction of BGSS from vegetation management. Over a three-year period (1996-98) at our experimental site at Conn Creek, near Yountville, catches of BGSS on sticky traps were reduced from 95 to 99% in the plot where vegetation had been removed and replaced compared to an adjacent undisturbed control. A second experimental site, along the Napa River near Yountville, that had been cleared in 1996 also had large reductions (more than 70%) in activity of the BGSS; catches at a single trap near adjacent undisturbed vegetation accounted for a majority of the BGSS activity that we detected in the vegetation management plot.
2. The most common major breeding hosts of BGSS in Napa and Sonoma riparian zones were California mugwort, Himalayan or California blackberry, wild grape, elderberry, and large periwinkle.
3. Less commonly occurring but highly preferred breeding hosts were Mexican tea, mulefat, stinging nettle, California Brickellbush, and cocklebur.
4. Trees planted in areas where mature trees had been removed in 1995 greatly exceed the growth of trees planted in competition with established trees
5. The natural infectivity of BGSS from experimental plots ranged from 5 to 45% over a three-year period at three sites. Very few BGSS could be tested for infectivity in the treatment plots because of their scarcity, so we could not assess the impacts of vegetation management on levels of natural infectivity of BGSS with the Pierce's disease bacterium.

This project led to results that should be implemented in the near future to reduce the impact of epidemic Pierce's disease along riparian habitats in coastal vineyards. The experimental management methods of removing relatively few species of plants drastically reduced populations of the primary vector (BGSS). The replacement plantings of riparian woodland species should increase biodiversity and long-term environmental quality of the managed sites. Reductions of BGSS activity should reduce the spread of Pierce's disease, but the circumstances and time

available for the project have not yet demonstrated effects on disease. We intend to evaluate these effects by following the spatial patterns of Pierce's disease that occur adjacent to the boundaries between our treatment and control plots in at least 2 of the 3 sites used in our study. Vineyards along the riparian study sites have been recently replanted, so it was not possible to collect adequate data on the effects of reducing BGSS activity in riparian zones on activity in adjacent vineyards.

Studies are in progress by other researchers to evaluate environmental impacts of riparian vegetation management. A work group convened under the leadership of the California Dept. of Fish and Game is now developing guidelines, based in part on the research reported here to enable grape growers to implement riparian management methods to reduce Pierce's disease while maintaining or improving environmental quality.

REFERENCES

Davis, M. J., Purcell, A. H. and Thomson, S. V. 1978. Pierce's disease of grapevines: isolation of the causal bacterium. Science 199: 75-77

Goodwin, P. and Purcell, A. H. 1992. Pierce's disease. *Grape Pest Management, 2nd Edition*. Oakland, University of California, Division of Agriculture and Natural Resources**:** 76-84.

Hewitt, W. B., Frazier, N. W. and Freitag, J. H. 1949. Pierce's disease investigations. Hilgardia 19: 207-264.

Hill, B. L. and Purcell, A. H. 1995. Multiplication and movement of *Xylella fastidiosa* within grape and four other plants. Phytopathology 85: 1368-1372.

Purcell, A. H. 1975. Role of the blue-green sharpshooter, *Hordnia circellata*, in the epidemiology of Pierce's disease of grapevines. Environ. Entomol. 4: 745-752.

Purcell, A. H. 1976. Seasonal changes in host plant preference of the blue-green sharpshooter *Hordnia circellata* (Homoptera: Cicadellidae). Pan-Pac. Entomol. 52: 33-37.

Purcell, A. H. 1981. Vector preference and inoculation efficiency as components of resistance to Pierce's disease in European grape cultivars. Phytopathology 71: 429-435.

Purcell, A. H. 1989. Homopteran transmission of xylem-inhabiting bacteria. *Advances in Disease Vector Research, Vol. 6*. K. F. Harris. New York, Springer-Verlag**:** 243-266.

Severin, H. H. P. 1949. Life history of the blue-green sharpshooter *Neokolla circellata*. Hilgardia 19: 187-189.

ABBREVIATIONS

BGSS: Blue-green sharpshooter
PD: Pierce’s disease of grapevines

LIST OF PUBLICATIONS

None yet produced. A manuscript should be completed for submission near the end of 1999.

APPENDIX 1 – TABLES

Table 1. Summaries of blue-green sharpshooter activity (total captures on yellow sticky traps) along riparian vegetation treatments and adjacent vineyards where present during the 1998 spring and summer seasons.

	Treatment					
Location	Vegetation Management		Undisturbed Control		Planted Buffer	
	Mar-June	July-Sept	Mar-June	July-Sept	Mar-June	July-Sept
Conn Creek*						
Riparian Corridor	0	1	116	108	79	186
Vineyard	re-planting	re-planting	Re-planting	re-planting	re-planting	re-planting
Napa River*						
Riparian Corridor	26	16	44	67	none	
Vineyard	52	15	29 [a]	36		
Maacama Creek**						
Riparian Corridor	48	13	78	57	none	
Vineyard	53	4	7	4		

* Initiated 3/12/98
** Initiated 3/30/98
[a] traps 100-200 feet from west riparian edge in scattered vines due to vine removal from PD.

Table 2. Summary of total yellow sticky trap catches of the blue-green sharpshooter on three sites in 1997.

Riparian Zone	Treatment		Total BGSS Traped in 1997 Number	
			March-June	July-Sept.
Conn Creek				
	East Levee	Clear-Plant	0	3
	Gamble	Control	141	77
		Control vineyard	re-plant	re-plant
		Buffer	149	65
		Buffer vineyard	re-plant	re-plant
	West Levee	Clear-Plant	1	0
	Gamble	Control	275	55
		Control vineyard	re-plant	re-plant
		Buffer	58	51
		Buffer vineyard	re-plant	re-plant
	East Levee	Buffer	7	39
	Krug	Control	28	9
		Control vineyard	17	1
	West Levee	Buffer	8	3
	Krug	Buffer vineyard	0	1
		Control	18	9
		Control vineyard	7	0
Napa River				
	East Levee	North Control	28	30
		North vineyard	4	3
	Silverado	South Cleared	25	17
		South vineyard	7	5
	West Levee	North Control	76	46
	Berr-Miller	North vineyard	129	108
		South Cleared	4	4
		South vineyard	6	9
Maacamas Creek	Simi	South Levee	254	229
		South vineyard	49	2
		North Levee	110	147
		North vineyard	11	3

Table 3. Summary of yellow sticky trap catches of the blue-green sharpshooter in 3 sites in 1996.

			Total BGSS Trapped in 1996	
Riparian Zone	**Treatment**		**Number**	
			March-June	July-Sept.
Conn Creek	East Levee	Remove-Replant	1	3
	Gamble	Control	66	63
		Control vineyard	22	28
		Buffer	114	132
		Buffer vineyard	63	131
	West Levee	Remove-Replant	5	5
	Gamble	Control	244	183
		Control vineyard	46	108
		Buffer	144	198
		Buffer vineyard	31	113
	East Levee	Buffer	3	10
	Krug	Control	53	148
		Control vineyard	31	27
	West Levee	Buffer	5	93
	Krug	Buffer vineyard	0	65
		Control	15	43
Napa River	East Levee	North Control	57	23
	Silverado	South Cleared	79	22
		South vineyard	13	14
	West Levee	North Control	108	162
	Beringer -Miller	North vineyard	278	223
		South Cleared	42	17
		South vineyard	0	8
Mayacamas				.
Creek	Simi	South Levee	47	418
		South vineyard	55	390
		North Levee	15	9

Table 4. Sweep net sampling (25 sweeps/sample) of blue-green sharpshooters (BGSS) in 31 riparian corridors (Napa, Sonoma, Mendocino) on 14 days from March 11 through July 6, 1998.

Plant	No. of Samples	BGSS Adults		BGSS Nymphs	
		Total	Per Sample	Total	Per Sample
Mexican tea	7	7	1.00	83	11.86
Brickellbush	7	0	0	47	6.71
Mugwort	112	250	2.23	651	5.81
Cocklebur	25	6	0.24	136	5.44
Mule fat	14	0	0	62	4.43
Stinging nettle	24	11	0.46	88	3.67
Wild grape	96	89	0.93	299	3.11
Himalayan blackberry	94	95	1.01	147	1.56
California blackberry	50	17	0.34	66	1.32
Elderberry	53	21	0.40	69	1.30
Lamb’s quarter’s	15	0	0	10	0.67
Periwinkle	80	17	0.21	7	0.09
Arroyo willow	71	10	0.14	1	0.01
Spice bush	30	7	0.23	0	0
Wild rose	27	3	0.11	0	0
Red willow	62	5	0.08	0	0
Sandbar willow	52	4	0.08	0	0
Yellow willow	30	2	0.07	0	0
Wild plum	18	1	0.06	0	0
California bay	109	5	0.05	0	0
Poison hemlock	21	1	0.05	0	0
Snowberry	47	2	0.04	0	0
Buckeye	74	2	0.03	0	0

The following plants (and sample numbers) had no BGSS in the 1998 survey: white alder (33), Oregon ash (48), big-leaf maple (21), box elder (56), black oak (19), coast live oak (92), cottonwood (22), valley oak (49), walnut (83), coyote brush (17), poison oak (32), and white sweet clover (14).

Table 5. Summary of four years of sweep net samples on the major food and breeding host plants of the adult and nymph Blue-green sharpshooter in Napa, Sonoma, and Mendocino Counties.

Host Plant		**No Sweep net**	**Adults per Sample**		**Nymphs per Sample**	
		Samples	Mean	±SE	Mean	±SE
Mugwort	1995	53	6.0	1.4	6.2	1.4
	1996	53	3.0	0.5	4.1	0.5
	1997	39	2.1	0.3	3.0	0.3
	1998	111	2.2	0.3	5.8	0.3
Himalayan Blackberry	1995	25	1.1	0.3	1.4	0.5
	1996	60	1.1	0.2	0.9	0.1
	1997	57	1.7	0.2	0.7	0.2
	1998	94	1.0	0.2	1.6	0.2
California Blackberry	1995	43	3.0	0.5	2.4	0.5
	1996	22	1.2	0.3	1.0	0.3
	1997	13	1.6	0.3	1.6	0.3
	1998	50	0.3	0.1	1.3	0.4
Wild Grape	1995	29	3.4	0.9	3.4	1.7
	1996	61	2.7	0.4	2.2	0.3
	1997	55	2.5	0.3	3.6	1.0
	1998	95	0.9	0.1	3.1	0.5
Periwinkle	1995	31	0.5	0.3	0.2	0.1
	1996	33	1.8	0.3	1.2	0.2
	1997	27	1.1	0.3	0.1	0.1
	1998	81	0.2	0.1	0.1	0.1
Elderberry	1995	21	1.2	0.5	0.4	0.1
	1996	27	1.7	0.3	0.9	0.2
	1997	19	2.2	0.3	0.1	0.1
	1998	52	0.4	0.1	1.3	0.2

Table 6. Summary of four years of sweep net samples on the less common but highly preferred breeding host plants of the adult and nymph BGSS in Napa, Sonoma, and Mendocino Counties.

Host Plant	Year	No. Sweep Samples	Adult per Sample Mean	±SE	Nymph per Mean	±SE
Cocklebur	1995	3	3.0	- - - -	1.33	- - - -
	1996	5	3.4	- - - -	0	- - - -
	1997	14	2.3	0.4	2.1	1.1
	1998	25	0.2	0.1	5.4	1.3
Stinging Nettle	1995	13	2.9	1.0	4.0	1.1
	1996	10	5.4	1.0	6.5	0.4
	1997	0	- - - -	- - - -	- - - -	- - - -
	1998	24	0.5	0.2	3.7	1.5
Lambs quarters	1995	6	5.3	- - - -	6.0	- - - -
	1996	11	1.8	0.4	0.4	0.2
	1997	0	- - - -	- - - -	- - - -	- - - -
	1998	15	0	0	0.7	0.5
Mulefat	1995	0	- - - -	- - - -	- - - -	- - - -
	1996	0	- - - -	- - - -	- - - -	- - - -
	1997	11	2.0	0.5	0.9	0.4
	1998	14	0	0	4.4	2.0
Brickellbush	1995	0	- - - -	- - - -	- - - -	- - - -
	1996	0	- - - -	- - - -	- - - -	- - - -
	1997	5	1.2	- - - -	3.4	- - - -
	1998	7	0	- - - -	6.7	- - - -
Mexican Tea	1995	0	- - - -	- - - -	- - - -	- - - -
	1996	0	- - - -	- - - -	- - - -	- - - -
	1997	0	- - - -	- - - -	- - - -	- - - -
	1998	7	1.0	- - - -	11.9	- - - -

Table 7. Native trees and shrubs sweep net summary for 1995 through 1998 in Napa, Sonoma, and Mendocino counties.

Native Plant	Total sweep Samples 95-98	Total Adults	Adult per Sample	Total Nymphs	Nymphs per Sample
Coast live oak	259	10	0.04	0	0.00
California bay	273	34	0.12	0	0.00
Buckeye	164	26	0.16	0	0.00
Valley oak	184	5	0.03	0	0.00
Walnut	255	37	0.15	0	0.00
Black oak	19	0	0.00	0	0.00
Bigleaf maple	59	1	0.02	0	0.00
Oregon ash	134	20	0.15	0	0.04
Box elder	126	15	0.12	0	0.00
White alder	94	2	0.02	0	0.00
Fremont cottonwood	59	7	0.12	0	0.00
Arroyo willow	153	81	0.53	37	0.24
Yellow willow	44	4	0.09	2	0.05
Red willow	190	69	0.36	10	0.05
Sandbar willow	162	46	0.28	4	0.02
Coyote brush	39	0	0.00	1	0.03
Wild plum	35	4	0.11	2	0.09
Wild rose	51	32	0.63	2	0.10
White sweet clover	39	0	0.00	0	0.00
Snowberry	101	24	0.24	10	0.12
Spice bush	49	11	0.22	0	0.14
Poison oak	51	3	0.06	0	0.00

Table 8. Range of natural infectivity of blue-green sharpshooter collected during late summer from three sites, 1996-98.

Location	Treatment	Year	Single insect infectivity	Groups of 5 infectivity	Date
Conn Creek					
	control	1996	48% of 21	33% of 115	Sept. 11, 19, &24
		1997	39% of 18		Sept. 7
		1998	15% of 20	18% of 85	Sept. 11, 14, &30
	managed	1998	0 of 2		Sept. 30
Napa River					
	control	1996	20% of 5	19% of 70	Sept. 24
		1997		18% of 70	Sept. 11&16
		1998	15% of 20	11% of 80	Sept. 18 & Oct. 30
	managed	1996	0% of 5	27% of 20	Sept. 24
		1997	9% of 11		Sept. 11
		1998	20% of 20	0% of 10	Sept. 17 & Oct. 5
Maacama Creek					
	control	1996	5% of 20	4% of 75	Sept 26
		1997	12% of 17	3% of 85	Sept. 17 & Oct. 16
		1998	8% of 13	0% of 65	Oct. 6
	managed	1998	0% of 7	0% of 10	Oct. 6

APPENDIX 2 - FIGURES

Figure 1. Height growth of planted seedlings of 10 tree species measured at the end of one year (1996) to three years (Dec. 1998) growth on the managed riparian corridor on Conn Creek (Napa Valley). The east bank location (no competition from established trees) of a species is indicated by "E". West bank locations (plantings under mature trees) are indicated by "W".

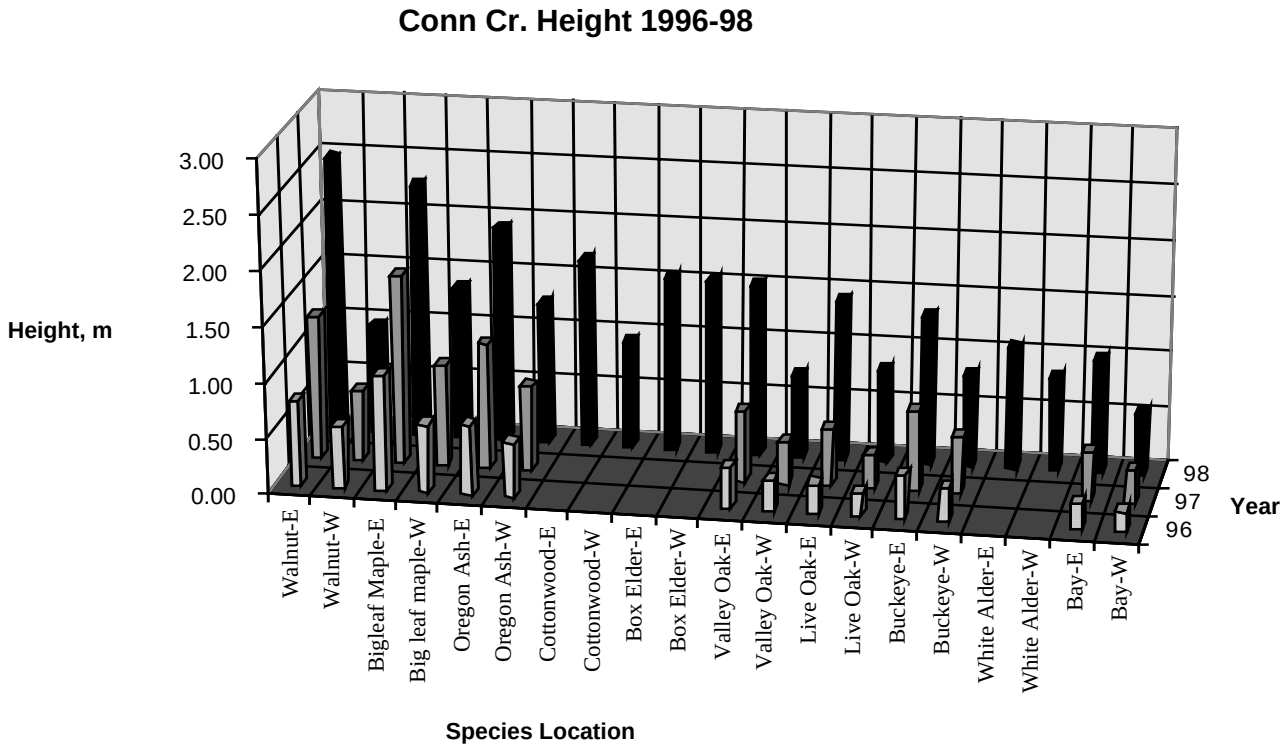

Figure 2. Sticky trap catches of blue-green sharpshooter (BGSS) at northern Conn Creek site, 1996. Data are presented for both the east (E) and west (W) sides of the creek. Note symmetries of catches in the cleared and replanted plot ("clear") and the undisturbed ("control") plots and the large differences in total catch between the treatment and control plots. Not all plots had adjacent vineyard plots (vineyard data not shown here). See also Table in Appendix 2 for summaries of total trap catches.