LUDWIGIA HEXAPETALA MANAGEMENT PLAN

FOR
THE LAGUNA DE SANTA ROSA
SONOMA COUNTY, CALIFORNIA

2005-2010

PREPARED BY
ANNA L. W. SEARS, LAGUNA DE SANTA ROSA FOUNDATION; AND
LILY N. VERDONE, SONOMA STATE UNIVERSITY AND THE MARIN/SONOMA MOSQUITO AND VECTOR CONTROL DISTRICT; ON BEHALF OF
THE SONOMA COUNTY *LUDWIGIA* TASK FORCE

FUNDING PROVIDED BY THE CALIFORNIA COASTAL CONSERVANCY, THE SONOMA COUNTY COMMUNITY FOUNDATION, AND THE MARIN/SONOMA MOSQUITO AND VECTOR CONTROL DISTRICT

*Contact: anna@lagunadesantarosa.org; verdone@sonoma.edu;

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I. PREFACE

This plan is a summary of our current knowledge about invasive *Ludwigia hexapetala* (*Ludwigia*) in the Laguna de Santa Rosa watershed, and the immediate and long-term strategies for *Ludwigia* management. It reflects contributions from the members of the Sonoma County *Ludwigia* Task Force, other stakeholders and interested parties in Sonoma County, and the science community. This is a work in progress. At this writing, *Ludwigia* is the subject of active scientific research, evaluating its ecology and the environmental triggers that promote explosive growth. As our knowledge evolves, this plan will also evolve.

II. INTRODUCTION

A. Site description and management goals

The Laguna de Santa Rosa (Laguna) is the largest tributary to the Russian River, and the second largest freshwater wetland in coastal California, draining a 254 mi^2 watershed. It is set in an open space/agricultural area of approximately 30,000 acres in a rapidly urbanizing portion of the North Bay Area, with more than 250,000 people residing within 10 miles of the principal channel. The central Laguna waterway is 14 miles long, with headwaters in the city of Cotati, emptying into the Russian River near Forestville. This channel is fed by more than 14 sub-tributaries, most entering the Laguna from the Santa Rosa Plain.

The Laguna ecosystem is a mosaic of open water, freshwater marsh, seasonal wetland, riparian forest, oak woodlands and grasslands. Some 232 bird species have been recorded in the Laguna, including many rare species with high conservation value. It is an important stopover for migrants on the Pacific Flyway, and the permanent home to a variety of wildlife which are dependent on its diverse habitat types. This ecosystem has been identified by local agencies and environmental groups as a focal point for environmental restoration, including restoration of the riparian corridor; improving water quality; and restoring fish, bird and wildlife habitats. The Sonoma County Agricultural Preservation and Open Space District (SCAPOSD) is acquiring land and easements and developing trail plans to increase public access in the Laguna. The Laguna de Santa Rosa Foundation (Laguna Foundation), has been funded by the Coastal Conservancy to develop a watershed restoration and management plan for the Laguna.

The wetlands of the Laguna naturally filter surface waters of nutrients, sediment and other impurities, before they enter the main channel of the Russian River. However, current inputs tax the natural capacity of this system. The US Environmental Protection Agency (EPA) has listed the Laguna as impaired for elevated nitrogen, phosphorus, sediment, temperature and low dissolved oxygen. These impairments arise from a combination of conditions: storm-water from the cities of Santa Rosa, Sebastopol, Cotati, Rohnert Park and Windsor drains into the Laguna; the City of Santa Rosa also uses the Laguna channel as a seasonal discharge point for treated wastewaters from its Laguna Treatment Plant; and there are additional sources of nutrients and sediment from roads, construction, and run-off of agricultural operations on the plain.

Historic removal of riparian vegetation along the channels of the Laguna and its tributaries likely contributes to increased water temperatures and nutrient influx. The North Coast Regional Water Quality Control Board (NCRWQCB), which has regulatory authority for

water quality in the Laguna has given high priority to the development of a Total Maximum Daily Load (TMDL) pollution control plan for the Laguna. This process will quantitatively assess water quality problems and sources of pollution, analyze the absorption capacity of the system, and evaluate actions to restore and protect beneficial uses of these waters. Many local community groups are concerned about water quality in the Laguna, and the TMDL process will likely be a broad-based effort.

Besides its value for conservation and regional water quality, the Laguna has an important role as a natural holding basin for seasonal floodwaters on the Santa Rosa plain, reducing localized flooding as well as down-stream floods along the Russian River. It is estimated that water levels in the city of Guerneville during the 1964 flood would have been 14 feet higher, if it were not for the Laguna floodplain's water-holding capacity[1]. However, a recent hydraulic analysis by the US Army Corps of Engineers (USACOE) found that the Laguna's flood control function is at risk from increased sedimentation in the channels and tributaries[2]. The study projects a 3 ft increase in Laguna flood levels over the next 40 years, with serious consequences to infrastructure in the surrounding area. The USACOE, in partnership with the Sonoma County Water Agency (SCWA) and the California Coastal Conservancy, is developing a plan for reducing sediment inputs and increasing hydraulic capacity in the Laguna system.

The Santa Rosa Plain has been the home to human settlements for more than 11,000 years. Native Americans used the Laguna's abundant resources, including oaks, tule and wildlife, to develop large, thriving communities. Today, the area has substantial agricultural value, with vineyards, ranches, dairies and a variety of smaller operations; and is home to hundreds of thousands Sonoma County residents. Agricultural operations provide high-quality food and employment, as well as the benefit of unimpeded open space and natural beauty. The relatively healthy economy, quality of life and good jobs in the region make the Laguna watershed one of the most desirable residential areas of the state, and leading to a local housing shortage. Thus, there has been rapid urban growth in the last decade and continuing pressure to develop many of the upland areas.

B. How *Ludwigia hexapetala* interferes with management goals

Ludwigia hexapetala is a rapidly growing aquatic shrub currently covering at least 150 acres of shallow-water areas in the Laguna ecosystem. *Ludwigia* has contributed to a public health threat as it creates protective habitat for mosquito species that can carry West Nile virus (WNV), which reached Sonoma County in 2004. Densely growing *Ludwigia* sharply inhibits current mosquito control efforts; and several Ludwigia-infested areas have been observed to produce mosquito populations more than 100 times greater than normally considered acceptable[3]. The Marin/Sonoma Mosquito and Vector Control District (MSMVCD) expended more than $80,000 for 2003-04 alone for mosquito control in *Ludwigia* areas, diverting resources and energy from other parts of the County. Vector Control operators have limited ability to control mosquitoes in these areas because dense *Ludwigia* growth inhibits larvacide applications. If larvacide can not be properly applied, operators must use

[1] See refs, SCFCWCD
[2] See refs, PW & A
[3] Marin/Sonoma Mosquito and Vector Control District, unpublished data

pyrethrin-based adulticides, which are less effective overall and tend to have greater negative impacts on fish. In addition, the stagnant eutrophic conditions associated with *Ludwigia* appear to favor 'foul-water' mosquito species that are superior vectors for West Nile virus (in the genus *Culex*).

Besides threatening public health, WNV has a potential to severely impact resident bird populations. The Laguna de Santa Rosa is a stop-over on the Pacific Flyway, and hosts a very diverse bird community. More than a third of the permanent or seasonal avian residents of the Laguna are thought to be vulnerable to WNV. Thirty-four of Laguna species are given priority conservation status under the Riparian Habitat Joint Venture, the North American Wetlands Conservation Act (NAWCA) for Coastal California wetlands, and/or California Department of Fish and Game (CDFG) list of Species of Special Concern (see Appendix C). Some of the Laguna's most numerically and ecologically dominant bird species are vulnerable to WNV, including herons, egrets, raptors, and corvids. Horses in surrounding farms are also vulnerable to the virus (one local fatality in 2004, and another in June 2005), which has unknown effects on other mammalian wildlife[4].

Ludwigia is also a direct threat to the diversity of native plant and animal communities, growing over surrounding vegetation to produce a thick mat of woody perennial stems and decaying plant matter. This mat inhibits the recovery and recruitment of other plants, and eliminates open-water habitats that are important foraging-grounds for birds and other wildlife. As *Ludwigia* tissue sloughs off and decomposes, microbial growth reduces dissolved oxygen in the water, impacting fish and invertebrate populations. Eighteen species of fish are found in the Laguna, including threatened populations of steelhead that use Laguna channels for seasonal passage to upstream spawning habitats.[5] Current efforts to protect and enhance Laguna wetland habitats for migratory birds and waterfowl on the Pacific Flyway are substantially limited by *Ludwigia* growth, especially in the CDFG's Laguna Wildlife Area where more than 100 acres of floodplain are covered with *Ludwigia.*

Ludwigia may also contribute to flooding in the Laguna system, as plant biomass fills in flood control channels, reducing its capacity for flood-retention and dramatically altering the characteristics of the wetland. Perennial *Ludwigia* mats slow the movement of water through the system, and likely act as a trap for fine sediments, further reducing capacity and degrading the wetland. Projecting current trends, with no remediation, *Ludwigia* will potentially lead to a decrease in shallow wetland areas overall, but with increased flooding during storm events.

C. Summary of *Ludwigia* biology

1. General description: *Ludwigia hexapetala* is an aquatic vascular plant; characterized by rapid growth, high nutrient accumulation and rapid decomposition. *Ludwigia* grows in transition zones of shallow, slow moving waterways. After establishing in the bank or channel bottom, prostrate stems grow laterally, rooting adventitiously at nodes. Once rooted, secondary shoots grow erect, up to 5 feet in height. *Ludwigia* reproduces primarily from asexual rooting plant fragments. Although it produces large quantities of seeds, seedlings are

[4] http://www.audubon.org/bird/wnv/pdf/effects_on_wildlife.pdf
[5] See refs, Smith 1990

rarely observed in nature. Rooting fragments are thought to be dispersed by water currents or by birds and other wildlife.

2. Taxonomy: The genus *Ludwigia* consists of 82 species worldwide, with the greatest diversity in South America, considered the center of origin for the *Ludwigia* genus and plant family (Onagraceae). The genus contains both herbaceous and woody species, as well as aquatic types. Many aquatic *Ludwigia* species are phenotypically plastic, such that their growth forms vary under different environmental conditions. This plasticity often complicates species-identification, and has led to a number of fluctuations in their taxonomic classifications. Chromosomal differences between species are sometimes used to aid taxonomy. *Ludwigia hexapetala* is a decaploid: 2n = 80 chromosomes; *Ludwigia peploides* subspecies *peploides*, *Ludwigia peploides* subspecies *montevidensis*, and *Ludwigia repens* contain 2n = 16, 16, and 32 chromosomes, respectively. *Ludwigia hexapetala's* large chromosome number is thought to contribute to its particularly vigorous growth. In this document, the genus name, *Ludwigia*, refers explicitly to *Ludwigia hexapetala*, except where noted.

3. Distribution: *Ludwigia hexapetala* is believed to have originated in Uruguay, as reflected by its synonym, *Ludwigia uruguayensis*, although there is still controversy among taxonomists as to whether it is also native to the United States. Its current distribution includes parts of Europe, the United States and South America. In Oregon, Southwestern Washington and California, *Ludwigia* is found at low elevations in rivers, streams, lakes, ponds, irrigation canals and other wet habitats. Whether native or non-native, *Ludwigia hexapetala* behaves as an aggressive, invasive species over most of its U.S. range. It is a noxious invasive species in many parts of the Southeast, including Florida and North and South Carolina. Researchers at the University of California, Davis, are initiating a genetic analysis of *Ludwigia hexapetala* in California, to better understand the biology and history of the invasion. Two other *Ludwigia* species have been documented in the Laguna watershed: *Ludwigia peploides* subspecies *peploides*, and *Ludwigia palustris*. *Ludwigia hexapetala* is currently the most abundant species, and is distributed in patches along the Laguna main channel and many of its tributaries – as well as along the Russian River. A comprehensive local mapping effort is underway. Herbariums at Sonoma State University and the University of California, Berkeley have specimens of Ludwigia hexapetala collected in Marin and Humboldt Counties from the 1940's, but the first specimens from Sonoma County were collected in 1988 on the Russian River south of Asti.

4. Biology: *Ludwigia hexapetala* is identified by its tall upright stature, bright yellow five-petal flowers and alternate, narrowly elliptic, lanceolate leaves, 5-10 cm long. *Ludwigia* persists perennially in Sonoma County. Growth from fragments embedded in soil or mud send out lateral shoots that root from nodes into submersed or seasonally exposed soils. Continued growth develops dense mats of emergent vegetation, covering shallow water areas and transitional margins. For *Ludwigia parviflora*, an abundant Asian rice-field weed, increases in soil-water content have been linked to increases in reproductive capacity and vegetative growth. This relationship has been observed, though not quantified in *Ludwigia hexapetala*. The amphibious character of *Ludwigia hexapetala* allows for only limited upland

survival; dry soils decrease its survivorship and reproductive ability, making it a poor competitor with other riparian and upland plant species.

Ludwigia is adapted to submersed or temporarily exposed soils as well as low-oxygen (anaerobic) conditions, through the presence of two distinct specialized root structures that extract oxygen and nutrients from the water column. Porous, upward growing aerenchymous roots provide a conduit for atmospheric gases to transfer throughout the plant in anaerobic conditions. Tightly packed cells of downward-growing adventitious roots (arising from the stem) absorb nutrients in the water column, often without contact with the substrate.

Along with the ability to tolerate low oxygen, *Ludwigia* appears to prosper in nutrient-rich water. *Ludwigia* species within have been studied as potential bioremediation agents for constructed wetlands and wastewater holding ponds. Experimental data on *Ludwigia peploides* reports growth increasing and leveling off with increased nitrogen concentrations. A similar study showed increased phosphorous and nitrogen concentrations in Ludwigia peploides tissue when exposed to effluent inundations. Initial research on *Ludwigia hexapetala* demonstrates a trend similar to that of *Ludwigia peploides*: increased nitrogen and phosphorous concentrations result in greater plant biomass.

III. OVERVIEW OF WEED MANAGEMENT PLAN

A. General management philosophy

Weed control is a necessary part of any restoration and management plan, in order to protect and maintain native species and communities and the stability of the environmental system. The Laguna is home to a great diversity of wetland and upland plants, which provide food and shelter to a great diversity of invertebrates, fish and wildlife. The overall goal is to proactively prevent the establishment of new weed species, and to set priorities for control of established weeds according to their actual and potential impacts on ecosystem processes, and native species and communities, particularly the rare and ecologically important species that are specific targets for conservation (such as Sebastopol Meadowfoam or Steelhead Trout). Action is recommended only after careful consideration indicates that leaving the weed unchecked will result in greater damage than risked by control efforts.

Weed control follows an adaptive management strategy. After establishing goals for the site, control areas are prioritized based on the severity of environmental impacts, and a control plan is developed based on this information. The plan is implemented in conjunction with a monitoring program, to evaluate the results of management actions. Methods are analyzed for effectiveness, and this information is used to modify and improve control priorities, methods and plans. Finally, the cycle is started again by establishing new or modified goals.

Ideally, priorities are geared toward minimizing the impact to non-target species, and minimizing the total, long-term workload. In general, the highest priority for weed control should be to prevent new infestations from taking hold, especially for species that are the fastest growing and most disruptive. However, large infestations of weeds with large environmental impacts, such as *Ludwigia hexapetala*, must also be given high priority. Weed

species which are not rapidly increasing in numbers, that don't move into undisturbed habitats or impact recovery from disturbance are a lower priority for control.

B. Summary of planned control actions

Ludwigia control plans were developed through a joint effort by the Sonoma County *Ludwigia* Task Force, convened in January 2003 to address the public and environmental health threats posed by *Ludwigia*. More than 50 local scientists, agency representatives, elected officials and representatives from environmental organizations have contributed to the planning effort. Control plans seek to follow an integrated pest-management (IPM) approach – based on the biology of the plant and on ecosystem-level restoration and management objectives. The integrated approach includes a variety of interim and long-term projects. Other aquatic weeds can also hinder control of mosquito populations; and the IPM approaches and Best Management Practices (BMPs) developed for *Ludwigia* will inform the management of other problem species in the Laguna watershed.

1. Summary of interim control alternatives

There are eight general alternatives for interim control of *Ludwigia* in the Laguna de Santa Rosa. The four most common alternatives are (1) 'no action'; (2) remove biomass manually or mechanically; (3) use systemic herbicides to kill plants; (4) use a combination treatment of herbicides and removal. To this list could be added other no-spray methods for killing *Ludwigia* plants, including (5) tarping; (6) flaming, or crushing; (7) techniques related to water-level management, such as flooding or draining; and (8) a more extensive biomass removal that includes mechanical excavation and dredging. Long-term control alternatives are described below.

a. No action: Because of *Ludwigia's* environmental impacts and accompanying risks to public health (described above), the 'no action' alternative is thought to have long-term negative impacts which will be difficult to mitigate. For these reasons, the first alternative is not desirable for the worst infested areas, although in Laguna locations where *Ludwigia* is now growing sparsely, the 'no action' alternative may be acceptable while other practices are being investigated. Leaving *Ludwigia* in place while attempting to manage mosquito levels may have ongoing negative impacts to resident fish species. Mosquito-control operators are not able to effectively apply larvacides to the water below densely-growing *Ludwigia*. Gambusia, mosquito-eating fish that consume *Ludwigia* larvae in other parts of the Laguna, do not appear to be effective in *Ludwigia* areas; the reasons for this are still unclear. Adulticide mosquito sprays are believed to be far less effective for mosquito control, and as these sprays are pyrethrum-based, although relatively safe for humans, they are quite toxic to fish (with greater toxicity than proposed herbicides, below).

b. No-spray alternatives: Above-ground biomass removal is possible using manual or mechanical methods, and is similar in principle to flaming or mechanically crushing plants to kill above-ground parts. However, *Ludwigia* is a perennial weed, that re-sprouts readily from root and stem fragments. For this reason, biomass removals that do not completely eliminate the root system, or that are not done in conjunction with an herbicide treatment to kill the roots, can result in rapid re-growth. This is similarly true of flaming and crushing methods, and ignition is likely to be difficult in this aquatic environment. Without killing the entire

plant, at best these methods have limited effectiveness, and at worst they produce fragments that can spread *Ludwigia* to other parts of the Laguna system. A study performed on behalf of the State Water Resources Control Board by the San Francisco Estuary Institute found that shredding plant material in stagnant water bodies (without removing shredded biomass) led to decreased dissolved oxygen, increases in nutrients, and an increased biochemical oxygen demand. Mechanical removal of above-ground plant material from shallow wetlands can create substantial disturbance, and ideally should be minimized.

Samples taken in 2003-04 suggest that dense *Ludwigia* areas have approximately 14 kilograms of wet-weight biomass per square meter. Extrapolating these estimates to the 150 acres of our project area, we approximate that as many as 9000 tons of *Ludwigia* should be removed. This number is likely to increase rapidly with time. Researchers in France found that in the field, *Ludwigia* can double in mass in 15-90 days, depending on conditions[6]. The massive quantities of biomass in the worst-infested areas make manual removal difficult. Workers at the City of Santa Rosa's Laguna Treatment Plant attempted to eradicate *Ludwigia* from their managed wetland by hand-pulling and raking in the worst infested areas for 2-6 person hours/week, and were only able to keep up with its growth. At the end of the season, *Ludwigia* covered 100% of the pond. However, hand-pulling is likely to be a good option for smaller infestations in highly managed areas. Volunteers in 2004 were able to clear *Ludwigia peploides* from the margins of a pond in the City of Sebastopol's Laguna Wetlands Preserve in approximately 150 person-hours of effort.

Mechanical excavation and dredging is a more comprehensive removal of *Ludwigia* plants and roots, and would have better success in eliminating *Ludwigia* from waterways, especially if dredged channels are made too deep for *Ludwigia* to successfully re-establish. However, concerns would remain about re-growth and fragmentation, and these methods represent a serious modification of the Laguna waterways. To excavate and dredge requires engineering and hydraulic analyses, and extensive oversight and permitting by the U.S. Army Corps of Engineers. As these studies take time, it is not likely that they could be implemented for the 2005 season, and perhaps not for several years. Tarping may be effective for killing *Ludwigia* plants down to the roots, although this technique has only begun to be tested on a small scale in the Laguna. It is likely that tarping extensive areas of wetland for an extended period of time would have great collateral damage on Laguna fish and wildlife populations.

c. Herbicide options: In response to the *Talent* decision, finding that discharge of pollutants from the use of aquatic pesticides must be covered by National Pollution Discharge Elimination System (NPDES) permits[7], the San Francisco Estuary Institute was commissioned to do a study of the effectiveness of no-spray alternatives on various weed species[8]. One of these studies specifically compared the effectiveness of herbicide spraying (glyphosate), mechanical removal, and combined spray/removal treatment on *Ludwigia* in a Delta-area irrigation channel. This study found that mechanical removal alone was essentially ineffective, and that the combined treatment, though most expensive, gave the

[6] Alain Dutartre, Hydrobiologiste, Cemagref, personal communication
[7] See refs, SWRCB
[8] See refs, SFEI

most lasting control. The Sonoma County *Ludwigia* Task Force has recommended this approach for controlling *Ludwigia* in the Laguna.

2. Summary of interim control plans

To control *Ludwigia* growth in the near-term, systemic herbicides will be used for three years in an active control and monitoring effort. Following herbicide application, residual biomass will be removed, where feasible, so that decomposing plant material does not create further adverse impacts, such as decreasing dissolved oxygen levels in the water. Control operations will be adjusted to site-specific conditions, and may vary among and within treatment areas. Overall, control efforts will be undertaken with sensitivity to the Laguna ecosystem – seeking to minimize effects on non-target plants and wildlife. Following adaptive management principles, fine-tuned planning and control efforts will be based on monitoring information.

Near-term control plans are being developed jointly with long-term plans to make the Laguna wetlands more resistant to aquatic weed infestation. The worst infestations appear to be associated with symptoms of wetland degradation: thick sediments in shallow, slow-moving, nutrient-rich waters in full sun. Thus, long-term control of *Ludwigia* will likely require restoration of riparian areas; improved water quality by reducing nutrient loads and sedimentation; and possible channel modifications (potentially including sediment removal) to encourage higher-quality habitat development. These restoration measures would have additional benefits to native flora and wildlife and the overall health of the Laguna ecosystem. Long-term control must also be pursued within an adaptive management framework: making adjustments based on the response of *Ludwigia*, mosquito populations, and associated plant and wildlife communities. Determining optimal *Ludwigia* control strategies will require a concerted research effort. Certain projects, such as riparian restoration of key areas, may be initiated in a relatively short timeframe. Others, such as potential modifications of the flood-control system, need further study to determine the most effective actions. See Appendix D for a description of ongoing and proposed *Ludwigia* research projects.

IV. SPECIFIC CONTROL PLANS

A. Goals

Overall, the goal for *Ludwigia* is to sharply reduce its population numbers to alleviate negative impacts on the Laguna ecosystem, and to reduce and stabilize its population growth rate, so that it no longer spreads invasively. Reducing *Ludwigia's* abundance is the central objective of our near-term control plans. Stabilizing its population growth rate will likely require lasting changes in Laguna management practices, that will complement the broader restoration goals for the Laguna ecosystem. After *Ludwigia* is brought to manageable levels, and following riparian restoration, the Laguna channel will likely have a higher habitat value. Mosquito control can be implemented more effectively, reducing the threat of WNV to humans and wildlife. *Ludwigia* removal will restore open-water habitats and allow native vegetation to recover, providing feeding grounds for bird and wildlife populations. Riparian shading will reduce the vigor of *Ludwigia* and other invasive aquatic weeds, and stream-bank

vegetation will buffer sediment and nutrients entering the Laguna. Water quality should measurably improve, and hydraulic processes may revert to somewhat more natural patterns, reducing sedimentation and local flooding.

B. Interim control plans

1. Project Description

The objective of near-term control plans is to control *Ludwigia* in the two areas of the Laguna watershed that have the greatest infestations.[9] *Ludwigia* now covers close to 100 percent of these areas, comprising more than 150 acres of floodplain and waterways. Following the procedures described below, we expect to sharply reduce the abundance of *Ludwigia* from target sites over a two to three-year period. Treated areas will be monitored and mapped during and after this period for five years. Implementation will follow adaptive-management principles, fine-tuning site-specific planning and control efforts based on effectiveness and monitoring data.

2. Project site

Target areas for short-term *Ludwigia* control are the Laguna channel from approximately 200 meters west of Stony Point Road to the confluence of the Laguna and Gossage Creek in Rohnert Park; and the Wilfred/Bellevue flood control channel from Millbrae Avenue to its confluence with the Laguna channel; both managed by the SCWA; as well as the Laguna channel and flood-plain parcels of the Laguna Wildlife Area between Occidental and Guerneville Roads, managed by the CDFG.

3. Herbicide products

Ludwigia is a perennial species that regenerates readily from root and stem fragments. Therefore, systemic herbicides are required to effectively eliminate infestations. The two compounds that have had the greatest success in controlling *Ludwigia* species (including *L. hexapetala* and *L. peploides*), are glyphosate (trade names Aquamaster and Rodeo) and triclopyr (trade name Renovate), formulated for aquatic application. Glyphosate controls both broadleaf plants (such as *Ludwigia*) and monocots (e.g., grasses, reeds and sedges). Triclopyr controls only broadleaf plants, and is thus preferable in areas with desirable native monocots. Both of these products break down rapidly under the warm, standing-water conditions of *Ludwigia* areas during the proposed treatment time in the Laguna. Glyphosate adheres strongly to soil particles, with a low potential for runoff; and breakdown is primarily by microbes. Its half-life in pond water ranges from 12 days to 10 weeks. Triclopyr does not strongly adhere to soil particles. Its breakdown is primarily by microbes in soil, and by hydrolysis or photolysis in water. Triclopyr's half-life in water is from 2.8 to 14.1 hours, depending on season and depth. Another compound, imazapyr, may be a good option for the future, but has not yet been registered for aquatic use in California. See EXTOXNET[10] (in reference section, below), for more information. Aquatic herbicide applications are regulated under the Environmental Protection Agency's Clean Water Act (CWA), and require an NPDES permit issued by the NCRWQCB.

[9] See maps, Appendix F
[10] See refs, EXOTOXNET

During application, products are combined with surfactants or other adjuvants to improve their effectiveness as herbicides. Adjuvants are any product added to a spray solution to enhance or modify its performance. Surfactants are additives to improve the emulsifying, spreading, sticking and absorbing properties of liquids. These compounds are not always regulated under the CWA. Some surfactants have come under criticism for producing undesirable breakdown products. For this reason, the common aquatic herbicide surfactant Nonylphenol polyethoxylate (NPE) will not be used for *Ludwigia* control in the Laguna. Formulations will be chosen with the goal of limiting overall environmental impacts.

4. Readiness and permitting

At this time, staff of the CDFG and SCWA have applied for two separate Statewide General NPDES Permits for aquatic application of glyphosate herbicide (General Permit No. CAG 990005)[11], under the supervision of the NCRWQCB. CEQA is not required for herbicide applications under this permit, as glyphosate is not classified as a priority pollutant. Biomass removal operations will be conducted under a CEQA Categorical Exemption.
NOAA/National Marine Fisheries Service and CDFG biologists do not believe that this project will have negative impacts on salmonid species.

5. Project methods/timeline:

Nov 2004 – June 2005: Site-specific *Ludwigia* control plans will be finalized. Target areas will be surveyed and mapped to identify sensitive areas: for example, around mature riparian vegetation where herbicide must be applied with high-precision. Application and biomass removal will be timed for summer and early fall to avoid disturbance to migrating salmonids.

July 2005: Application of glyphosate to *Ludwigia* on approximately 25 acres of target flood control channels and 130 acres of flood plain in the Laguna Wildlife Area. Products will be applied from airboats, ATVs, amphibious vehicles or other ground or water-based equipment (no aerial spraying), according to site-specific application plans. Water-quality monitoring will take place prior to applications and repeated during and after treatments, in accordance with permit requirements.

August – September 2005: Removal of residual plant biomass where feasible, using terrestrial and/or aquatic harvesting equipment. Flood-plain areas are mostly accessible to modified agricultural harvesters and flood control channels can be harvested with small aquatic harvesters or using long-armed excavators working from existing roads. Biomass will be trucked out of the floodplain to be composted or tilled into the soil.

September 2005: Sow annual grass seed in *Ludwigia*-removal areas, where appropriate, to provide vegetative cover and stabilize soils. Annual grass will not survive extended flooding, so are not expected to interfere with natural recruitment of native perennial plants.

[11] See refs, SWRCB

May – June 2006: Survey and map remaining *Ludwigia* patches using GIS. Revise site-specific *Ludwigia* control plans, based on areas of re-growth.

July-September 2006: Repeat herbicide applications and remove residual plant material as necessary, following protocols, above, sowing grasses to stabilize exposed soils, as previous.

May-September 2007: Repeat surveys, revise site-specific control plans; repeat herbicide applications and remove residual plant material as necessary, sowing grasses to stabilize exposed soils, as previous.

6. Monitoring and Evaluating Success

To support the long-term goals of this project, the plant community in the target areas will be surveyed before herbicide applications begin. During and after herbicide applications and dead plant material removal, water quality will be monitored to test for product residues (to comply with regulatory requirements), increased nutrients, and sediment and decreased dissolved oxygen. To fine-tune subsequent herbicide applications, the percent cover of *Ludwigia* will be estimated in the year following treatments. Treatments effects on non-target native plant species will also be evaluated.

Ludwigia was first recognized as a serious environmental problem in the Laguna when the mosquito trap-counts in *Ludwigia* areas were found to be 100 times greater than normally acceptable levels (for example, 400 mosquitoes in a trap over a single night). Key indicators for project success will be (1) a sharp drop in mosquito trap numbers – showing a response to successful larvacide applications in the absence of *Ludwigia*; and (2) a shift from 'foul-water' species to fresh-water species that are relatively poor West Nile vectors. Mosquito trap-count and species data for 2003 and 2004 will provide a baseline for comparison.

Project reports and monitoring results will be made available to project funders, the Sonoma County *Ludwigia* Task Force, and the general public. To facilitate reporting, we hope to develop a database on the Russian River Interactive Information System (RRIIS). This community-based interactive system stores and distributes information on the Russian River watershed, and is funded by the California State Resources Agency and the US Army Corps of Engineers.

7. Risks to Well Water

The California Department of Pesticide Regulation (DPR) has indicated that the risk of well-water contamination by label-rates of glyphosate applications is very low: glyphosate has a high affinity for soil particles and is broken down by microbes. As part of their Groundwater Protection Program, between 1986 and 2004 DPR tested for glyphosate contamination in 4685 wells, in 51 counties.[12] Of these, there was only one sample with traces of glyphosate, and follow-up tests did not confirm detection.

8. Public outreach and education

As there is been some public concern about the use of herbicide within the Laguna, the *Ludwigia* Task Force has made efforts to garner public input and keep the public informed of plans and decisions. In the fall of 2004, the Fifth District Supervisor, Mike Reilly, convened two meetings with Laguna Foundation, MSMVCD, public health officers and interested environmental representatives to discuss the potential public and environmental health threats posed by WNV and *Ludwigia*, and potential strategies to address the *Ludwigia* problem. The environmental representatives acknowledged the severity of the problem, and voiced strong concern that any *Ludwigia* control program be conducted within the context of long-term restoration of the Laguna ecosystem, including the need to address Laguna nutrient issues. There was also strong concern over the use of nonylphenol polyethoxylate surfactants, which were consequently eliminated from consideration for this project. The Laguna Foundation has developed a website with current information on the *Ludwigia* Control Project[13], and has acted as a nexus for information and questions from the public. The local press has given much coverage to the issues of *Ludwigia* and West Nile virus, and reporters have attended most *Ludwigia* Task Force meetings. Representatives from the Laguna Foundation have made presentations on *Ludwigia* to a wide variety of public gatherings, to share information and answer questions about control plans. Two public workshop were held during April and May 2005, to discuss *Ludwigia* Control Project plans and NPDES permit applications.

C. Long-term control through restoration

Although the project described above will likely eliminate the worst *Ludwigia* infestations and relieve the risks of West Nile virus and other mosquito-borne diseases, small patches of *Ludwigia* will remain, scattered throughout the watershed. Short-term approaches need to be accompanied by long-term restoration plans to make ecological changes to the system that will prevent or reduce the impact of re-infestation. Thus, long-term control measures must also consider a broader geographic area. *Ludwigia peploides* is also known to occur in the Laguna watershed, and it is often difficult to distinguish these species in the field. Because of the presence of this native, and the logistical considerations involved with systematically eradicating every individual of *Ludwigia hexapetala* from the lakes, ponds and waterways of Sonoma County, our goal is to lessen its invasiveness and environmental impacts – rather than seek total eradication. This approach requires extensive ecological research, likely over a 5-10 year time frame. As *Ludwigia* is a relatively new pest species, there is little material in the scientific literature to draw from.

[12] http://www.cdpr.ca.gov/docs/gwp/index.htm
[13] http://www.lagunadesantarosa.org/RMP/Ludwigia/default.htm

A researcher at Sonoma State University has begun investigations on the response of *Ludwigia* to excess nutrients in the Laguna. Researchers with the USDA Agricultural Research Service (USDA-ARS) are also conducting experiments on restoration-based methods for *Ludwigia* control. The Sonoma County *Ludwigia* Task Force will work together with these researchers to develop a long-term *Ludwigia* management strategy, based on the best available science. Potential control measures include water level management, shading portions of the channel with riparian vegetation, reducing nutrient availability, and using biological control organisms; see Appendix D. As *Ludwigia* is beginning to create serious environmental problems elsewhere in the country and in Europe, there is great potential for developing a broad *Ludwigia* research consortium. At this stage we are collecting baseline and preliminary data, initiating research, and a comprehensive GIS mapping effort. As part of this baseline mapping effort, the USDA-ARS is taking high-resolution aerial photos and hyper-spectral images of the Laguna channels. These images will help track the progress of the invasion, and evaluate the success of interim control measures, as well as develop a set of environmental correlates to *Ludwigia* distribution.

Restoration projects, for weed management and habitat enhancement, need to be designed within the context of broader planning efforts. The Laguna Foundation has been funded by the Coastal Conservancy to develop a Restoration and Management Plan for the Laguna watershed. As the Laguna represents some of the highest-quality habitat in an area of high species diversity, there is great community interest in ecosystem restoration in this area.

V. ACKNOWLEDGEMENTS

This plan is loosely based on a Weed Management Template developed by Mandy Tu and Barry Meyers-Rice for The Nature Conservancy's Wildland Invasive Species Program. We are grateful for this and the many other resources made available through TNC. We would like to thank the members of the Sonoma County *Ludwigia* Task Force and the many other interested parties who have contributed ideas and material to this plan. We are very grateful to the funders of this plan: the California Coastal Conservancy, the Sonoma County Community Foundation, and the Marin/Sonoma Mosquito and Vector Control District; as well as the funders of the Interim *Ludwigia* Control Project: The Sonoma County Water Agency, the Wildlife Conservation Board, the Santa Rosa Subregional Reclamation System, and the Marin/Sonoma Mosquito and Vector Control District.

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VII. APPENDICES

Appendix A. Index of Acronyms

BMP: Best Management Practice
CDFG: California Department of Fish and Game
CEQA: California Environmental Quality Act
DPR: Department of Pesticide Regulation
CWA: Clean Water Act
GIS: Geographic Information System
IPM: Integrated Pest Management
MSMVCD: Marin/Sonoma Mosquito and Vector Control District
NAWCA: North American Wetlands Conservation Act
NCRWQCB: North Coast Regional Water Quality Control Board
NOAA: National Oceanic and Atmospheric Administration
NPDES: National Pollution Discharge Elimination System
RRIIS: Russian River Interactive Information System
SCAPOSD: Sonoma County Agricultural Preservation and Open Space District
SCWA: Sonoma County Water Agency
TMDL: Total Maximum Daily Load
USACOE: United States Army Corps of Engineers
USDA-ARS: United States Department of Agriculture – Agricultural Research Service
WNV: West Nile virus

Appendix B. Sonoma County *Ludwigia* Task Force Members, June 2005

Allan Buckmann; Wildlife Biologist, California Department of Fish and Game
Dick Butler; Team Leader, National Marine Fisheries Service
Denise Cadman; Natural Resource Specialist, City of Santa Rosa
Caroline Christian, Ph.D.; Senior Scientist, Plant Ecologist, the Nature Conservancy
Gene Cooley; Botanist, California Department of Fish and Game
Bill Cox; Fisheries Biologist, California Department of Fish and Game
David Cuneo; Senior Environmental Specialist, SCWA
J. Hall Cushman, Ph.D.; Conservation Biologist, Sonoma State University Faculty
Keenan Foster; Botanist, Senior Environmental Specialist, SCWA
Brenda Grewell, Ph.D.; USDA-ARS Exotic and Invasive Weed Research, Davis CA
Leigh Hall, M.D.; Deputy Public Health Officer, Sonoma Co. Department of Health Services
Erik Hawk; Vector Ecologist, Mosquito Vector Control District
Andrew Jensen; Environmental Scientist, NCRWQCB
Ron Keith; Entomologist, Mosquito Vector Control District
Piper Kimball; Vector Ecologist, Mosquito Vector Control District
Chris Kjeldsen, Ph.D.; Aquatic Botanist, Sonoma State University Emeritus Faculty
Chuck Krause; Operations Manager, Mosquito and Vector Control District
Walter Kruse; Director, Sonoma County Environmental Health
Dan Logan; Fisheries Biologist, National Marine Fisheries Service
Bruce MacArthur; Deputy Ag. Commissioner, Sonoma Co. Agricultural Commission
Jake MacKenzie, Ph.D.; City of Rohnert Park, Aquatic Botanist, retired EPA regulator
Bob Rawson; Wastewater Management Consultant, Russian River Watershed Council
Jim Raisner; Agricultural Biologist, Sonoma Co. Agricultural Commission
Mike Reilly; Fifth District Supervisor, Sonoma County Board of Supervisors
Anna Sears, Ph.D.; Research Director, Laguna de Santa Rosa Foundation
Dan Schurman; Executive Director, Laguna de Santa Rosa Foundation
John Short; Senior Water Resource Control Engineer, NCRWQCB
Mike Thompson; Deputy Chief Engineer for Maintenance, SCWA
Joel Trumbo; Pesticide Use Coordinator, California Department of Fish and Game
Lily Verdone; Plant Ecologist, Biology Master's program, Sonoma State University
Jim Wanderscheid; Manager, Mosquito and Vector Control District

Appendix C. Bird species of concern that will benefit from this project

The following birds are residents of the Laguna de Santa Rosa within the vicinity of the project area and are Riparian Habitat Joint Venture focal species, CDFG species of special concern, or priority species under the North American Wetlands Conservation Act (NAWCA) for Coastal California freshwater wetlands. Susceptibility to West Nile Virus (WNV) is noted where known.

Riparian Habitat Joint Venture focal species

Common Yellowthroat (breeding populations)**
Song Sparrow (breeding populations)**
Wilsons Warbler (breeding populations)**
Yellow Warbler (breeding populations)* CSC
Warbling Vireo (breeding populations)**

Priority NAWCA Waterfowl species:

Mallards (breeding populations)**
Wood Duck (breeding populations)*
Lesser Scaup (winter resident)**
Greater Scaup (winter resident)**
American Widgeon (winter resident)
Ring-neck Duck (winter resident)

Priority NAWCA species

Northern Harrier (breeding populations)** CSC
American Avocet (breeding populations)
Allen's Hummingbird (breeding populations)
Violet-green Swallows (breeding populations)
Marsh Wren (breeding populations)
Warbling Vireo (breeding populations)*
Black-headed Grosbeak (breeding populations)**
Hooded Oriole (breeding populations)**
Bullock's Oriole (breeding populations)
Loggerhead Shrike (breeding populations) CSC
Cooper's Hawk (winter resident)** CSC
Short-eared Owl (winter resident)** CSC
Olive-sided Flycatcher (summer resident)**
Western Wood-peewee (summer resident)
Black-bellied Plover (migratory)
Short-billed Dowitcher (migratory)
Lazuli Bunting (migratory)
Lewis' Woodpecker (migratory)**

Other CDFG Species of Special Concern

Double-crested Cormorant (breeding populations)** CSC
Osprey (breeding populations)** CSC
Golden Eagle (breeding populations)** CSC
American White Pelican (winter resident)** CSC

* – Species listed as affected by WNV by USGS National Wildlife Health Center
** – Species that have tested positive for WNV by the Federal Center for Disease Control
"**CSC**" – CDFG 'Species of Special Concern'

Note: Absence of positive test does not indicate that species are immune to WNV. Small or rare populations may not yet have been tested.

Appendix D. Important Areas for *Ludwigia* Research

1. Overview

Information on *Ludwigia's* taxonomy and biology is currently very limited, making it difficult to determine optimal control strategies. Understanding the basic ecology of *Ludwigia's* dispersal mechanisms, its taxonomy and ecosystem function in the Laguna as well as its potential ecological interactions is essential for both long and short term watershed management planning. Initial research plans were in conjunction with the *Ludwigia* Task Force and have assisted with the interim planning process. There remain numerous unanswered questions requiring extensive research. These multifaceted questions affect a wide base of community, economic and natural resource management issues such as agriculture, water management and flooding and human health.

2. Current *Ludwigia* research

A Master's researcher at Sonoma State University is investigating the growth of *Ludwigia* under varied nitrogen and phosphorous nutrient regimes. This study is rooted in the ecological theory that invasive species competitively prosper in nutrient rich environments, like the Laguna: listed by the EPA for elevated nitrogen and phosphorus among other impairments. *Ludwigia hexapetala* growth rates will be compared with potential competitor wetland plant species such as the native *Ludwigia peploides*. The research is being conducted in mesocosms (small tanks), and complemented by observational field data on growth rates and nutrient levels. Additional ongoing research projects include experimental evaluation of non-herbicide control measures, such as tarping, manual removal and grazing.

3. Planned *Ludwigia* research

***i.* Population biology and natural history:** There are many holes in our knowledge of *Ludwigia* and its growth dynamics in Sonoma County. To begin with, it is necessary to develop better markers for species identification, because native *Ludwigia* species are similar to the invasive in physical appearance and apparent habitat requirements. Understanding individual and population-level growth dynamics and constraints will be key for long-term management planning; for example, modeling *Ludwigia* rate of spread and dominant mechanisms of dispersal. It is also important to analyze the ecological differences between *Ludwigia* species. The ability to quantify *Ludwigia* growth under different environmental conditions (water depth, nutrient availability) could be used to control populations in invaded areas and to predict potential invasion sites.

***ii.* Community ecology**: The Laguna is a diverse watershed with many rare and endangered species. Thus it is important to understand how *Ludwigia* invasions affect surrounding plant and animal species. *Ludwigia's* primary competitive strategy is to overgrow neighboring plants, starving them of space and light. Where *Ludwigia* plants form monocultures, birds, insects, fish and other wildlife may be affected, as well as surrounding wetland plants. Understanding these relationships will affect the specific planning of management practices, and potentially the prioritization of control actions. Plant-animal interactions are complex and interconnected. Invading plant species can detrimentally affect food webs, habitat and competitive interactions. With regional efforts to protect habitat for endangered salmonids, it would be very useful to understand the effect of *Ludwigia* on juvenile fish, amphibians, and invertebrates. It would also be

valuable to quantify the effects of *Ludwigia* on habitat quality for waterfowl and migrating birds in the Pacific Flyway. Physical, ecological, and physiological differences between local *Ludwigia* species may influence their interactions with insects, parasites and plant pathogens: providing avenues for potential species-specific biological control mechanisms.

***iii.* Interactions with hydrology and sedimentation:** *Ludwigia* appears to have a fairly limited ecotone, or set of conditions for optimal growth. Water-level and flow-rate are thought to be central drivers of *Ludwigia* distribution patterns and reproductive success. Thus, water-level management is a potentially powerful tool for *Ludwigia* control, manipulating levels by strategically draining or deepening areas of the Laguna. However, Laguna water-levels are dynamic, changing throughout the year, so it is difficult to quantify the specific conditions or regimes favoring *Ludwigia* growth as well as the growth and well-being of neighboring plant and animal species. Knowing which conditions favor different suites of species is absolutely necessary for evaluating the direct and indirect effects of water-level changes on the wetland community and abiotic processes.

Thick, vegetative mats of *Ludwigia* biomass in the main channel potentially effect movement of sediment, water flow and flooding. Although the effects of sedimentation on *Ludwigia* have not been quantified, *Ludwigia* appears to favor soft, sediment-rich soils. It is also likely that Ludwigia mats trap sediments moving through the Laguna waterways. This process of accretion and further growth may act as a positive feedback-loop, accelerating channel infill, and assist in *Ludwigia's* habitat expansion. Sediments may also facilitate *Ludwigia* growth by providing a consistent source of nutrients.

Appendix E. MAP

Top priority sites for *Ludwigia* control in the Laguna de Santa Rosa (see http://www.lagunadesantarosa.org/RMP/Ludwigia/Appendix_F_Ludwigia%20map.pdf).

Appendix F. HERBICIDE LABEL AND MATERIAL SAFETY DATA SHEET

1. Rodeo label (glyphosate product)
   http://www.cdms.net/ldat/ld4TN002.pdf

2. Rodeo Material Safety Data Sheet (MSDS)
   http://www.cdms.net/ldat/mp4TN006.pdf