Memorandum

Date: July 22, 2016

To: Ms. Lynn Sadler
   Deputy Director
   Department of Parks and Recreation

From: Sandra Morey, Deputy Director
       Ecosystem Conservation Division

Subject: Risk Assessment for Uruguay waterprimrose (*Ludwigia hexapetala*)

Per the August 26, 2014, letter requesting risk assessments for five species of aquatic plants identified by the California Department of Parks and Recreation as potentially invasive, please find enclosed the California Department of Fish and Wildlife’s (CDFW) risk assessment findings and determination regarding Uruguay waterprimrose (*Ludwigia hexapetala*). Per Harbors and Navigation Code, section 64.5, CDFW included in their assessment:

- Whether Uruguay waterprimrose may obstruct navigation and recreational uses of waterways;
- Whether Uruguay waterprimrose may cause environmental damage, including threats to the health and stability of fisheries, impairment to birds’ access to waterways and nesting, roosting, and foraging areas, deterioration of water quality resulting from plant decay, and harm to native plants;
- Whether Uruguay waterprimrose may cause harm to the state’s economy, infrastructure, or other manmade facilities such as state water storage facilities and pumping operations, by increasing flood risk, threatening water supplies by blocking pumps, canals, and dams necessitating early control efforts; and
- Whether Uruguay waterprimrose causes or is likely to cause any other harm to California’s environment, economy, or human health or safety.

To ensure thorough consideration of the species’ ecological characteristics and the specified impacts and threats, CDFW employed the U.S. Aquatic Weed Risk Assessment tool. As specified in sec. 64.5, CDFW consulted with the Department of Food and Agriculture, the Department of Water Resources, the State Water Resources Control Board, the Department of Pesticide Regulation, and the Office of Environmental Health Hazard Assessment, to develop the risk assessment findings and determination.

As fully detailed within the enclosed risk assessment, CDFW concludes that Uruguay waterprimrose should be considered an invasive aquatic plant that causes or is likely to cause economic or environmental harm or harm to human health in California.
CDFW staff have completed a draft risk assessment for coontail (*Ceratophyllum demersum*), which is currently undergoing internal review. CDFW staff has begun assessment of Carolina fanwort (*Cabomba caroliniana*), the fifth of five previously requested assessments, and will soon begin assessment of floating pennywort (*Hydrocotyle ranunculoides*), per your July 13, 2016 request.

If you have any questions regarding this risk assessment, or the others in process, please contact Ms. Martha Volkoff, Habitat Conservation Planning Branch, Invasive Species Program, at (916) 651-8658 or by email at Martha.Volkoff@wildlife.ca.gov.

Enclosure

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INTRODUCTION

The California Department of Parks and Recreation’s Division of Boating and Waterways (DBW) is the lead agency of the State for the purpose of cooperating with other state, local, and federal agencies in identifying, detecting, controlling, and administering programs to manage, control, and when feasible, eradicate invasive aquatic plants in the Sacramento-San Joaquin Delta, its tributaries, and the Suisun Marsh. Harbors and Navigation Code (HNC) §64.5 defines an “invasive aquatic plant” as an aquatic plant or algae species, including its seeds, fragments, and other biological materials capable of propagating that species, whose proliferation or dominant colonization of an area causes or is likely to cause economic or environmental harm or harm to human health. Per HNC §64.5, for aquatic plant species that DBW believes may be invasive and desires to manage, control, or eradicate, DBW shall request that the California Department of Fish and Wildlife (CDFW) conduct a risk assessment to determine if the species causes or is likely to cause economic harm or environmental harm or harm to human health. The risk assessment shall be documented in a way that clearly describes the severity and types of impacts caused or likely to be caused by a plant species determined to be an invasive aquatic plant. Within 60 days after completing the risk assessment, CDFW shall report its findings to DBW.

DETERMINATION

Per DBW’s August 26, 2014 request, CDFW evaluated whether Uruguay waterprimrose, *Ludwigia hexapetala*, should be considered an invasive aquatic plant in California. To make the determination, CDFW selected a quantitative assessment tool that evaluated aspects of the species’ ecology, reproductive potential, dispersal mechanisms, competitive ability, actual and potential impacts (including impacts to navigation and recreation, the environment, economy, and human health as specified in HNC §64.5), and resistance to management. Based on this evaluation and the findings contained herein, CDFW, in consultation with California Department of Water Resources (DWR), State Water Resources Control Board (SWRCB), Department of Food and Agriculture (CDFA), Department of Pesticide Regulation (DPR), and Office of Environmental Health Hazard Assessment (OEHHA), determines that Uruguay waterprimrose (UWP) is an invasive aquatic plant that causes or is likely to cause economic or environmental harm or harm to human health in California.
**CURRENT DISTRIBUTION**

Waterprimroses are a complex of species belonging to the genus *Ludwigia*, Family Onagraceae. *Ludwigia* species identification can be challenging due to morphological similarities and a history of varying identification in the literature. It is generally accorded that *Ludwigia hexapetala*, the species requested by DBW for assessment, was previously considered synonymous with *L. grandiflora* and *L. grandiflora* ssp. *hexapetala* (DiTomaso et al. 2013), all here referred to by the common name Uruguay waterprimrose, though recent genetic and taxonomic work indicates that *L. grandiflora* and *L. hexapetala* may be separate species (Zardini et al. 1991; Nesom and Kartesz 2000; DiTomaso et al. 2013).

UWP is native to South America, and has been introduced and is considered invasive in temperate to sub-tropical areas of North America (United States), Europe (Great Britain, Ireland, France, Belgium, Switzerland, the Netherlands, Germany, Spain, Italy, Turkey), Africa (Kenya), Australia, and New Zealand (EPPO 2011; Thouvenot et al. 2013). In France, UWP is considered to be the country’s most invasive aquatic plant (Thouvenot et al. 2013). UWP was originally introduced into most countries, including the United States, intentionally as an ornamental aquatic plant for water gardens (Verdone 2004; Kaufman and Kaufman 2013). In the United States, UWP was introduced by the early 1900s (Kaufman and Kaufman 2013), though the timing of its introduction into California is not clear. UWP has been present in California as a naturalized weed for several decades (Cal-IPC 2016); however, it was not recognized for its invasive tendencies until recently. In Sonoma County, UWP has been present since at least 1975, but only began spreading around 2000 (Verdone 2004). UWP is now present throughout much of California, and has been documented in each of the following geographic regions, as classified by the State Wildlife Action Plan (CDFW 2015): Central Valley and Sierra Nevada, Cascades and Modoc Plateau, North Coast and Klamath, throughout the Bay-Delta and Central Coast, including the East, West, North, and South (San Francisco) Bay, and South Coast (Calflora 2016).

UWP (*Ludwigia hexapetala*) is listed by CDFA as a noxious weed, and is categorized as having a “high” (severe) level of negative ecological impacts in California (Cal-IPC 2006). Outside of California, UWP is identified as invasive or regulated as noxious, restricted, or prohibited in the states of FL, OR, WA, NC, SC, and OK (CISEH 2013; USDA-NCRS 2014; ODA 2016; ODWC 2016).

**RISK ASSESSMENT**

UWP was assessed using the U.S. Aquatic Weed Risk Assessment (USAqWRA) tool, which was modified for the U.S. by Gordon et al. (2012) from the New Zealand Aquatic WRA model (Champion and Clayton 2001). The USAqWRA functions as the aquatic alternative to the Australian WRA, which is widely accepted and applied, but inaccurately classifies nearly all aquatic species as invasive, thus requiring modification for the accurate assessment of aquatic plants (Gordon and Gantz 2011). The USAqWRA has been tested for accuracy and validated under the environmental conditions of the U.S. and is the only assessment tool developed for the U.S. that maximizes accuracy for aquatic plants and incorporates all of the factors outlined in HNC §64.5.

The USAqWRA defines non-invaders as having no evidence of establishment outside of cultivation (in non-native ranges). Minor invaders are defined as species that have established in non-native ranges, but with no described ecological impacts. Major invaders are defined as having established in non-native ranges, and having documented, negative ecological impacts. Species are categorized using a scoring system of <31 (non-invaders), 31 – 39 (evaluate further), and >39 (major invaders). Gordon et al. (2012) determined that using the threshold score of 39 to distinguish major invaders from both minor and non-invaders maximized overall accuracy of the assessment tool at 91%.

CDFW conducted a thorough search of peer-reviewed journals and government publications to accurately complete the assessment. The resulting evaluation of UWP invasiveness (Appendix A) produced a score of 76 predicting UWP to be a
“major invader” of the Sacramento-San Joaquin Delta. The findings using the USAqWRA model are summarized below, along with additional findings relevant to assessing potential impacts.

**ECOLOGY**

UWP is an emergent, perennial macrophyte that exhibits an annual growth pattern. UWP dies back each winter, but the submerged or buried roots and rhizomes of established UWP plants survive winter temperatures as low as -11°C (12.2°F) and new shoots emerge from the rhizomes in the spring when temperatures reach 12 – 15°C (53.6 – 59°F), typical of springtime temperatures in the Delta (EPPO 2011; Santos et al. 2011; Thouvenot et al. 2013). Though UWP is an emergent plant, it is also known to creep on land; stems may become bushy and/or climb on other plants (Thouvenot et al. 2013; Hoch and Grewell 2016). UWP displays a high level of phenoplasticity depending on its environment (Hussner 2010; Lambert et al. 2010). Stems, when floating, are glabrous and produce white, spongy roots at the nodes; when erect, stems are spreading-hairy (Hoch and Grewell 2016). Growth occurs primarily in late spring and summer; once stems reach the water surface, rosettes of leaves are formed, after which branching occurs (EPPO 2011; Thouvenot et al. 2013). UWP flowers from late spring through fall; in the early winter, emergent parts of the plant break up and die back (Thouvenot et al. 2013; Califlora 2016).

UWP is common in a wide variety of habitats, including rivers, streams, irrigation canals, drains, lakes, ponds, marshes, and wet meadows (Branquart et al. 2007; Rolon et al. 2008; Hernandez and Rangel 2009; Haury et al. 2011; Thouvenot et al. 2013). It is limited by flow velocity, but does colonize river margins (EPPO 2011). UWP can be found at depths of up to 3 m, but generally prefers shallow water between 0.6 and 1 m; stems can emerge up to 0.8 m above the water surface (Lambert et al. 2010). UWP is tolerant of flooded, partially flooded, and drained soils (Hussner 2010). UWP tolerates fluctuating (by 3 m) water levels by differential production of root and shoot biomass, likely an advantage under predicted climate change models (Hussner 2010). UWP requires flooded or aquatic conditions to settle, but after establishment will tolerate moist terrestrial conditions for years (Haury et al. 2011). UWP is not limited by soil type or pH and can be found growing in mud, peat, sand, or gravel ranging from acidic to alkaline conditions (Hussner 2010; EPPO 2011; Thouvenot et al. 2013). UWP is a strictly freshwater plant and does not tolerate salinities in excess of 6 ppt (EPPO 2011). It grows best in mesotrophic to eutrophic waters, but is tolerant of oligotrophic conditions (Hussner 2010). Due to its production of pneumatophores, UWP is tolerant of anoxic conditions (EPPO 2011; Thouvenot et al. 2013).

**REPRODUCTIVE POTENTIAL**

UWP reproduces both sexually and vegetatively, through rhizomatous growth and fragmentation. Plant stems and rhizomes of UWP readily fragment year-round; stem fragments are buoyant and produce adventitious roots (EPPO 2011; Thouvenot et al. 2013). Plants produce yellow flowers from May to December in California (Calflora 2016), with shortened bloom periods in cooler climates (Thouvenot et al. 2013). Fruiting occurs in the fall, with dense infestations (> 80% cover) producing seed capsules on up to 70% of stems; potential seed set can reach up to 10,000 seeds/m² (DiTomaso and Healy 2003; Ruaux et al. 2009). Each capsule contains up to 59 seeds, which remain within fruits during dispersal. Capsules may float for more than 3 months, during which time they are dispersed by wind, water currents, fish, and aquatic birds (Ruaux et al. 2009; Thouvenot et al. 2013). Seed viability has been reported as high as 75%, though viability is reduced by over 50% when temperatures fall below freezing (Ruaux et al. 2009).

Though UWP seeds persist at least overwinter, length of seed viability is unclear and germination cues are unknown (Ruaux et al. 2009; EPPO 2011). Though polyploid species such as UWP (2n = 80) often have increased seedling survival (Zardini et al. 1991; Okada et al. 2009; USDA-ARS 2016), Verdone (2004) suggests the UWP population in the Laguna de Santa Rosa (Sonoma County, California) produces sterile seeds. Further, Okada et al. (2009) suggest that California populations spread almost exclusively via vegetative reproduction, finding that within each of 27 distinct populations across California, 95% of ramets belonged to a single genet.
**DISPERAL MECHANISMS**

Due to its attractive yellow flowers and shiny, dark green leaves, UWP was originally imported into the United States as an ornamental plant for use in horticulture and water gardens. Original populations are believed to have been established when the plant escaped or was dumped from unwanted water gardens (Ruaux et al. 2009; Thouvenot et al. 2013). UWP has also been intentionally planted as part of bioremediation efforts, as it sequesters nutrients very effectively (Verdone 2004). UWP populations have been present in California for decades as a naturalized non-native, but around 2000 began aggressively expanding and invading habitats (Meisler 2009). UWP expansion and dispersal occurs primarily vegetatively, through fragmentation, given that germination of UWP seeds in the field appears to be uncommon in California (Okada et al. 2009). Plant fragments and seed capsules may float for as long as 3 months and are readily dispersed by wind and water currents (Verdone 2004; Ruaux et al. 2009; DiTomaso et al. 2013; Thouvenot et al. 2013; Hoch and Grewell 2016). Fragments are also easily transported via human activities and may be transported by watercraft, trailers, and equipment (Verdone 2004; DiTomaso et al. 2013). UWP also spreads via animal-mediated dispersal; aquatic birds and fish may consume seed capsules and transport them to new locations, and waterfowl are thought to transport UWP fragments in their plumage (Verdone 2004; Ruaux et al. 2009).

**COMPETITIVE ABILITY**

When conditions are favorable, UWP is able to out-compete established native vegetation, both aquatic and terrestrial, and is considered to be a transformer or engineer species as it is capable of covering entire waterbodies and altering water quality (Verdone 2004; Lambert et al. 2010). Due to its matting growth, which shades other aquatic plants, UWP is able to out-compete species of other growth forms, including both submerged and floating aquatic vegetation (Stiers et al. 2011).

Recognizing the limitations of *Ludwigia* identification, CDFA reports, according to their observations, waterprimrose is among the most widespread and competitive of all aquatic plants in low-elevation, slower-moving, shallower waterbodies in California. In the Delta, it is in constant and intense competition with water hyacinth (*Eichhornia crassipes*) and floating pennywort (*Hydrocotyle ranunculoides*) to control the edges of channels or shallow flats, and the winner can change with location or time. CDFA reports having seen it outcompete and replace water hyacinth in undisturbed, shallow sloughs. Where it is competitive, it usually grows as a monoculture. UWP is not recognized for being able to significantly invade and displace tule stands or well-established cattails, but few other plants seem able to withstand it (P. Akers, CDFA, personal communication). In less favorable conditions, UWP may not be able to outcompete established vegetation, but will rapidly colonize previously de-vegetated areas or newly created habitat, especially in areas with disturbed hydrology and high nutrient loading (Verdone 2004; Lambert et al. 2010). Rate of UWP expansion is very rapid under ideal conditions. At Laguna de Santa Rosa, UWP reached 100% cover in over 3 miles of main channel within 2 years (1,450 acres; Verdone 2004). It often chokes out areas that are less than several feet in depth or slow-moving channels that are less than perhaps 40 feet wide (P. Akers, CDFA, personal communication).

**REALIZED AND POTENTIAL IMPACTS**

**Obstruction of Navigation and Recreation**

Both above and below the water surface, UWP forms expansive mats of dense vegetation that impede many recreational activities, including boating, swimming, fishing, and hunting (Verdone 2004; EPPO 2011). UWP infests main channels as well as shorelines, and recreational access from shore can be impossible in areas of dense cover (EPPO 2011). UWP is capable of clogging channels and boat launches to the extent that boating is no longer possible, or is severely restricted (Meisler 2009). In severe infestations, waterbodies may be closed (Thouvenot et al. 2011).
According to CDFA, in California UWP presents major problems for boat access, or any other activity, is generally one of the major nuisances for marinas and boat ramps, and can stall even powerful boats (P. Akers, CDFA, personal communication). Boat propellers easily become tangled in the underwater stems of UWP and can chop UWP into fragments that float downstream, exacerbating the problem (Meisler 2009). Fishing and hunting access is similarly limited; fishing gear easily tangles in UWP mats, and fishing opportunities decrease as the underwater mats can be so dense as to impede fish movement (Verdone 2004). Although UWP dies back in the winter, decaying mats of UWP continue to impede recreational activities as well as decrease their appeal (Thouvenot et al. 2013).

**Environmental Effects**

**Water quality** – Dense mats of UWP cause a variety of environmental impacts, including chemical, hydrological, and ecological (Dandelot et al. 2005; EPPO 2011). Ecological and economic problems caused by UWP are so severe this species is considered the most invasive aquatic weed in France (Thouvenot et al. 2013) and a “transformer species” (Dandelot et al. 2005). UWP alters water quality and chemistry in areas of heavy infestation by reducing water flow, increasing sedimentation, and creating anoxic conditions through decomposition, root respiration, and its dense growing condition, which prevents surface exchange of oxygen and reduces light so submerged plants are unable to photosynthesize effectively (Dandelot et al. 2005; EPPO 2011). Water under UWP mats also has higher sulfide and phosphate concentrations, and lowered sulfate and nitrate concentrations (CABI 2014).

**Native plants** – A primary ecological impact of UWP is the reduction in the abundance and diversity of plants and animals. UWP has been shown to significantly reduce native plant abundance and diversity in both Europe (Dandelot et al. 2005; EPPO 2011; Stiers et al. 2011) and in California (Verdone 2004). In Belgium, infestations of UWP decreased native plant species richness by 70% compared to uninvaded areas; < 25% cover of UWP reduced species richness similarly to 100% cover of UWP (Stiers et al. 2011). In addition to out-competing native vegetation and invading newly created habitat (Lambert et al. 2010), UWP reduces competition via production of allelopathic compounds that decrease germination, increase mortality, disrupt seedling elongation, and induce chlorosis in other terrestrial and wetland species (Dandelot et al. 2008).

**Birds and waterfowl** – Bird habitat is severely degraded in areas heavily infested with UWP (Verdone 2004). Access to feeding areas, both from the shore and from above, becomes limited due to large mats of UWP (Kaufman and Kaufman 2013). As UWP reduces plant species abundance and diversity, food sources become more limited as well, although some waterfowl will consume UWP (Verdone 2004). The Delta, including the Laguna de Santa Rosa, is a part of the Pacific Flyway, and the UWP infestation in the Laguna has already reduced available feeding, nesting, breeding, and resting sites (Verdone 2004). Additionally, over one-third of bird species found in the Laguna are susceptible to West Nile Virus, most commonly vectored by mosquitoes of the genus *Culex*, for which UWP provides ideal habitat (Sears et al. 2006).

**Health and stability of fisheries** – In areas of dense growth, UWP also reduces biodiversity of native fauna, specifically fishes and invertebrates, likely by a combination of anoxic conditions and unsuitable substrate (heavy mats of decaying plant matter) (EPPO 2011; Stiers et al. 2011). In UWP invaded ponds in Belgium, increased invasive plant cover was negatively correlated (n = 22, r = -0.46, P < 0.05) with invertebrate abundance (Stiers et al. 2011). In UWP invaded (> 50% cover) ponds, invertebrate abundance was reduced by approximately 60% compared to uninvaded ponds, significantly reducing an important food source for fish populations (Stiers et al. 2011). Dense matting of underwater stems also excludes fish (Dandelot et al. 2005; EPPO 2011; Thouvenot et al. 2013). High densities of UWP become a barrier impeding fish passage, including migrations of salmonids through...
the Delta (Verdone 2004). Water amid UWP mats is also characteristically low in oxygen levels, which also reduces fish presence (Dandelot et al. 2005; EPPO 2011).

**Economic, Infrastructure, or Man-made Facilities**

UWP’s habit of dense, matting growth in slow flowing water clogs irrigation and drainage canals, leading to impacts on water delivery for irrigation (EPPO 2011). Canals can provide ideal conditions for rapid biomass production; total infested area can double in as few as 15 days, exacerbating impacts to water delivery (EPPO 2011). However, CDFA suggests canals with higher rates of flow and steeper banks may provide less suitable conditions for UWP growth (P. Akers, CDFA, personal communication). Dense growth of UWP slows water velocities, increasing sedimentation rates and leading to increased risk of flooding (Meisler 2009). Additionally, UWP is a successful invader of wet and flooded meadows and displaces wetland grasses, but has low palatability to cattle and horses and can lead to reduced forage quality and increased feed costs for livestock farmers (EPPO 2011). A separate, but similar, species of waterprimrose, *Ludwigia hyssopifolia*, is a major weed of rice crops in Asia (Chauhan et al. 2011); the Delta is an important region for rice-growers in California and UWP has the potential to become a major weed in California’s rice fields.

**Human Health**

Dense mats of UWP restrict water flow, creating ideal habitat for mosquito reproduction, especially primary vector species (*Culex* spp.) for West Nile virus (Sears et al. 2006). Additionally, UWP’s dense surface growth inhibits effective (in-water) application of mosquito larvicides, necessitating aerial or broadcast applications of less-effective adulticides (Sears et al. 2006). In the Laguna de Santa Rosa, record numbers of mosquitoes were captured by the Marin/Sonoma Mosquito and Vector Control District near dense growth of UWP in 2004, the same year that West Nile Virus arrived in the area (Meisler 2009). As a result, a task force was formed to implement a multi-year control effort for UWP in the Laguna (Meisler 2009).

UWP’s dense, matting growth can lead to increased water levels and flooding by slowing flow velocities and trapping sediments (Meisler 2009). Submerged aquatic plants, such as Eurasian watermilfoil (*Myriophyllum spicatum*) and hydrilla (*Hydrilla verticillata*), have been recognized for entangling swimmers in their dense underwater growth, in some cases leading to drowning (CAST 2014). Although UWP is not a submerged plant, and no studies have been found investigating its potential for contributions to drownings, given its dense, matting growth of underwater stems it is possible that UWP infestations could also contribute to drownings.

**Resistance to Management**

UWP can be controlled by various means, including hand removal, mechanical harvesting, cultural control, shading, biological control agents, and herbicides (Pine and Anderson 1991; Meisler 2009; Harms and Grodowitz 2012; DiTomaso et al. 2013; Hernández and Walsh 2014). Hand removal can be effective, but is time-consuming and impractical over large areas with dense cover. Mechanical harvesting, as found in the Laguna de Santa Rosa UWP control effort, produces UWP fragments that can float downstream, creating new populations and adding to existing ones (Meisler 2009). In the case of the Laguna de Santa Rosa, a pathway had to first be cleared by chopping a path through the UWP, creating numerous plant fragments, each capable of forming a new plant (Meisler 2009). These fragments had to be collected downstream using a silt screen attached to a floating boom (Meisler 2009). Once a path was cleared and herbicide could be applied, in some areas removal of the sprayed vegetation was determined to be prohibitively expensive, and had to be left in place (Meisler 2009).

Herbicide application can be problematic in areas of dense growth, where UWP is often thick enough to prevent even airboat passage. With adequate access, herbicides are an effective measure; DiTomaso et al. (2013) offers multiple
options, several of which (glyphosate, 2,4-D, and imazamox) are registered with the U.S. Environmental Protection Agency and the California Department of Pesticide Regulation and are currently utilized by DBW in their treatment of floating aquatic vegetation in the Delta (L. Ramos, DBW, personal communication).

The aforementioned active ingredients are currently allowed for use under the Statewide General National Pollutant Discharge Elimination System Permit for Residual Aquatic Pesticide Discharges to Waters of the United States from Algae and Aquatic Weed Control Applications, Water Quality Order 2013-0002-DWQ. However, if additional aquatic pesticide active ingredients approved by DPR are proposed to be used for UWP control other than 2,4-D, acrolein, calcium hypochlorite, copper, diquat, endothall, fluridone, glyphosate, imazamox, imazapyr, penoxsulam, sodium carbonate peroxyhydrate, sodium hypochlorite and triclopyr-based algaecides and aquatic herbicides, and adjuvants containing ingredients represented by the surrogate nonylphenol, the SWRCB can amend the above referenced permit to add the DPR-approved aquatic pesticide(s). The amendment process typically requires around 4 months to process and is initiated by written request to the SWRCB-Division of Water Quality (R. Norman, SWRCB, personal communication).

As suggested by DiTomaso et al. (2013), cultural control would involve reducing nutrient loading and managing flood/dry conditions. However, cultural control may not be a viable management option given conditions in the Delta and UWP growth habits. There may be multiple options for biological control, primarily by insects (Pine and Anderson 1991; Harms and Grodowitz 2012; Hernández and Walsh 2014). Research has been conducted to identify specialist insect feeders on UWP, with some success (Harms and Grodowitz 2012; Hernández and Walsh 2015). However, the presence of a native Ludwigia spp. in California complicates the prospect of biological control. Grass carp will consume UWP, but preferentially feed on many other species before consuming UWP (Pine and Anderson 1991).

Only one case of eradication of UWP is thought to have been successful; a population in Southern England (Lambert et al. 2010). In England, UWP is not yet widespread, as it is in California (Gallardo and Aldridge 2013). In California, control efforts in the Laguna de Santa Rosa (herbicide and mechanical measures) produced mixed results (Meisler 2009). Success varied with channel depth; deeper channels retained reduced regrowth for up to 4 years, but shallow channels displayed significant regrowth each year (Meisler 2009). All Ludwigia removed from the Laguna de Santa Rosa was placed and composted on agricultural lands adjacent to the area it was removed. The remnant plants composted well, had no adverse odor, and easily incorporated into the soil once degraded (E. Larson, CDFW, personal communication).

Assessing UWP infestations in the Delta may be more difficult due to the potential presence of other Ludwigia species, some native and others also considered invasive. Given that few studies have been conducted on UWP invasion and management, USDA-ARS (2016) is currently conducting experiments on Russian River and Delta populations of UWP to evaluate factors influencing the establishment, spread, and management of Ludwigia species. Results from this study, which is expected to be completed in September 2016, may be useful in informing management decisions.

REFERENCES


Ludwigia hexapetala (Hook. & Arn.) Zardini, Gu & Raven

Calflora. 2016. Information on California plants for education, research and conservation, with data contributed by public and private institutions and individuals, including the Consortium of California Herbaria [online database]. The Calflora Database [a non-profit organization]. Berkeley, California. (July 2016).


## APPENDIX A: Risk Assessment of Uruguay waterprimrose, *Ludwigia hexapetala*

### Species: Uruguay waterprimrose; *Ludwigia hexapetala*

<table>
<thead>
<tr>
<th>Question - USAqWRA</th>
<th>Score and guidance – USAqWRA</th>
<th>Score</th>
<th>Justification</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1 Temperature tolerance</td>
<td>(0-3) Score 3 if maintains photosynthetic tissue and summer growth form throughout winter, 2 if dies back to tuber/bulb/rhizome (or similar structure) during winter, 1 if adult plants completely die but viable seeds remain. Use a climate matching tool if direct evidence is not available. Default = 1 for annual species.</td>
<td>2</td>
<td>Dies back to rhizomes over winter. Minimum growth temperatures are 12-15 °C; can survive below -11 °C.</td>
<td>EPPO 2011; Thouvenot et al. 2013</td>
</tr>
<tr>
<td>1.2 Range of habitat</td>
<td>(1-3) Score 3 if able to grow from water to dry land, 2 if water to wetland, or from shallow to deep (&gt;5 m) water, 1 narrow range. Default = 1 if no information is available; 2 for free-floating plants, unless more information is available.</td>
<td>2</td>
<td>Prefers shallow water, but grows in water up to 3 m deep. Can survive on flooded to drained soils.</td>
<td>Lambert et al. 2010; Haury et al. 2011</td>
</tr>
<tr>
<td>1.3 Water/substrate type tolerance</td>
<td>(1-2) Score 2 if tolerant of sandy to muddy (or peaty) substrate, or oligotrophic to eutrophic waters, 1 if restricted by either. Default = 1 if no information is available.</td>
<td>2</td>
<td>Grows in nutrient-poor to nutrient-rich soils and gravel/sand.</td>
<td>Hussner 2010; EPPO 2011; Thouvenot et al. 2013</td>
</tr>
<tr>
<td>1.4 Water clarity tolerance</td>
<td>(0-1) Score 1 if unaffected by water clarity (i.e. floating or emergent, or submergents tolerant of very low light levels, such as <em>Myriophyllum spicatum</em> and <em>Hydrilla verticillata</em>), 0 if affected by water clarity.</td>
<td>1</td>
<td>Emergent plant, thus unaffected by water clarity.</td>
<td>Thouvenot et al. 2013; Hoch and Grewell 2016</td>
</tr>
<tr>
<td>1.5 Salinity tolerance</td>
<td>(0-1) Score 1 if species can tolerate saline conditions, 0 if not. Habitat information can be used to determine a score of 0 if species is only found to occur in freshwater habitats.</td>
<td>0</td>
<td>Intolerant of salinities in excess of 6 ppt.</td>
<td>EPPO 2011</td>
</tr>
<tr>
<td>1.6 pH tolerance</td>
<td>(0-1) Score 1 if tolerant of both acidic and basic pH or no information is available, 0 if restricted to neutral, basic, or acidic pH.</td>
<td>1</td>
<td>Tolerant of both acidic and alkaline conditions.</td>
<td>Thouvenot et al. 2013</td>
</tr>
<tr>
<td>1.7 Water level fluctuation - Tolerates periodic flooding/drying</td>
<td>(0-3) Score 3 for species which have evidence of tolerating periodic flooding/drying with a specified time period longer than 1 month (e.g., &quot;months&quot;; &quot;X months&quot;, &quot;winter flooding&quot;), 2 for evidence of tolerance of flooding/drying over a period of days/a couple of weeks, 1 for species that die back during periods of flooding/drying, and 0 for species that do not tolerate flooding/drying. Do not score if there is no information available.</td>
<td>3</td>
<td>Requires water for colonization, but once established as a terrestrial plant can survive for years.</td>
<td>Haury et al. 2011</td>
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<tr>
<td>2.1 Lentic - rivers, streams, drains, or other flowing waters, including their margins</td>
<td>(0-3) Score 3 if major weed (reaches high density and dominates plant community), 2 if minor weed (common, but rarely or never dominant), 1 if present but not weedy, 0 if absent.</td>
<td>2</td>
<td>Present along river margins. Prefers slow-flowing waters.</td>
<td>EPPO 2011; Thouvenot et al. 2013</td>
</tr>
<tr>
<td>2.2 Ponds, lakes and other standing waters, including their margins</td>
<td>(0-3) Score 3 if major weed (reaches high density and dominates plant community), 2 if minor weed (common, but rarely or never dominant), 1 if present but not weedy, 0 if absent.</td>
<td>3</td>
<td>Dominates in standing waters.</td>
<td>Verdone 2004; Stiers et al. 2011; Thouvenot et al. 2013</td>
</tr>
<tr>
<td>2.3 Swamp, marsh, bog, or other wet areas not covered by 2.1 or 2.2</td>
<td>(0-3) Score 3 if major weed (reaches high density and dominates plant community), 2 if minor weed, 1 if present but not weedy, 0 if absent.</td>
<td>3</td>
<td>Dominates in standing waters.</td>
<td>Verdone 2004; Stiers et al. 2011; Thouvenot et al. 2013</td>
</tr>
<tr>
<td>2.4 Establishment – into existing vegetation</td>
<td>(-5, -3, 0) Score 0 if able to invade unmodified vegetation, -3 if the species can only colonize certain types of vegetation (e.g., turf-forming shoreline vegetation), -5 if there is no evidence that the species can move into intact vegetation. Default = 0 if there is evidence of establishment, but no specific information about level of invasion into existing vegetation and/or type of vegetation being invaded. Default = -3 for species that have not naturalized outside of their native range.</td>
<td>0</td>
<td>In favorable conditions, can out-compete existing native vegetation.</td>
<td>Lambert et al. 2010</td>
</tr>
<tr>
<td>2.5 Establishment – into disturbed vegetation</td>
<td>(0, 1, 5) Score 5 if able to aggressively colonize following vegetation clearance, newly constructed waterbodies or nutrient enrichment, 1 if the species grows in disturbed areas, but there is no other information, 0 if there is no evidence of establishment in disturbed areas. Information from either the native or introduced range may be used to answer this question. Default = 1 for no information.</td>
<td>5</td>
<td>Aggressively colonizes disturbed areas of vegetation.</td>
<td>Lambert et al. 2010; EPPO 2011; Thouvenot et al. 2013</td>
</tr>
<tr>
<td>3.1 Competition – between growth form</td>
<td>(0, 1, 2) Score 2 if species forms dense stands that are documented to displace other growth forms (submerged, floating, emergent), 1 if some suppression, 0 if no displacement. Default = 0 if species has been in the trade globally for &gt;30 years and there is no information about the species displacing other growth forms.</td>
<td>2</td>
<td>Displaces wetland grasses and native floating and submerged plants by shading.</td>
<td>EPPO 2011; Stiers et al. 2011</td>
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<td>4.1 Dispersal outside catchment by natural agents (e.g. birds, wind)</td>
<td>(0, 1, 3, 5) Score 5 if species (including seeds, rhizomes, fragments etc.) well adapted, and likely to be frequently dispersed, by natural agents, 3 if transport by natural agents is possible but uncommon, 1 if propagule could be spread in bird crop, 0 if no, or extremely low, likelihood of dispersal by natural agents (e.g., Hydrilla is scored 1 because its turions can survive passage through duck guts, an agent of dispersal, but this is believed to happen rarely).</td>
<td>5</td>
<td>Floating fragments and propagules readily disperse via wind and water currents. Fish and birds also facilitate dispersal. Sexual reproduction is minimal in CA, but seed capsules can float for 3 months.</td>
<td>Verdone 2004; DiTomaso and Healy 2003; Ruaux et al. 2009; Thouvenot et al. 2013</td>
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<td>4.2 Dispersal outside catchment by accidental human activity</td>
<td>(1, 2, 3) Score 3 if major pathway, seeds/fragments adapted for easy transportation (e.g., via boat/trailer, fishing gear), 2 if the species is a floating plant or a macrophyte, but no explicit mention of high spread in the literature, 1 not mentioned, not likely to be spread by human activity based on growth form and life history. Default = 1 if no information is available.</td>
<td>3</td>
<td>Fragments are easily transported by human activities.</td>
<td>Verdone 2004; DiTomaso et al. 2013; Thouvenot et al. 2013</td>
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<td>4.3 Dispersal outside catchment by deliberate introduction</td>
<td>(0-1) Score 1 if species is desirable to humans (e.g., or used for medicinal, food, ornamental, restoration, etc. purposes in the U.S. or elsewhere). If species is not used or no information exists, score should be 0.</td>
<td>1</td>
<td>Originally imported into the U.S. as an ornamental. Produces some medicinal compounds. Used for nutrient sequestration.</td>
<td>Verdone 2004; Ruaux et al. 2009; Thouvenot et al. 2013</td>
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<td>4.4 Effective spread within waterbody/catchment</td>
<td>(0-1) Score 1 for extensive spread within a waterbody or among waterbodies, 0 for no spread. Occurrence along streams or riverbanks or in rivers can be used as evidence, as well as evidence of water dispersal. Do not answer if no information is available.</td>
<td>1</td>
<td>Populations expand via rhizomatous growth and readily disperse via floating fragments.</td>
<td>Thouvenot et al. 2013</td>
</tr>
<tr>
<td>5.1 Generation time (time between germination of an individual and the production of living offspring, not seeds or other dormant structures)</td>
<td>(1, 2, 3) Score 3 if rapid (reproduction in first year and &gt;1 generation/year), 2 if annual or produces one generation every year including the first year, 1 if not reproductively mature in the first year. Default = 1 if no information is available.</td>
<td>3</td>
<td>Plants readily fragment beginning immediately after germination.</td>
<td>Thouvenot et al. 2013</td>
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<td>6.1 Seeding ability - Quantity</td>
<td>(0-3) Score 3 if &gt;1000 seeds/plant/year, 2 100-1000, 1 &lt;100 and/or evidence that seed are produced (in native or introduced range), 0 if seed not produced.</td>
<td>2</td>
<td>Each fruit capsule contains up to 59 seeds, with many fruits per plant.</td>
<td>Ruaux et al. 2009</td>
</tr>
<tr>
<td>6.2 Seeding ability - Viability/persistence</td>
<td>(0-2) Score 2 if highly viable for &gt;3 years, 1 low viability or evidence of seed production with no information on viability, 0 no viable seeds.</td>
<td>1</td>
<td>Seed viability very low in California; no information on length of seed viability. Plant primarily spreads vegetatively.</td>
<td>Verdone 2004</td>
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<tr>
<td>7.1 Vegetative reproduction</td>
<td>(0, 1, 3, 5) Score 5 for naturally fragmenting from rhizomes, stolons, or other vegetative growth into tissue capable of producing new colonies (e.g., Egeria densa), 3 if produces rhizomes/stolons, but there is no other information about the formation of new colonies elsewhere, 1 for clump-forming by vegetative spread, 0 for no vegetative spread.</td>
<td>5</td>
<td>Extensive rhizomatous growth. Readily fragments and forms new plants.</td>
<td>Okada et al. 2009; Thouvenot et al. 2013</td>
</tr>
<tr>
<td>8.1 Physical–water use, recreation</td>
<td>(0-2) Score 2 for major nuisance, 1 for minor nuisance. Default = 0 if the species has not naturalized outside of its native range. If there is a reasonable amount of information about the species and it has naturalized outside of its native range, default = 0.</td>
<td>2</td>
<td>Completely covers waterways, impeding recreation.</td>
<td>Thouvenot et al. 2013</td>
</tr>
<tr>
<td>8.2 Physical – access</td>
<td>(0-2) Score 2 for major nuisance, 1 for minor nuisance. Default = 0 if the species has not naturalized outside of its native range. If there is a reasonable amount of information about the species and it has naturalized outside of its native range, default = 0.</td>
<td>2</td>
<td>Due to its tendency to grow in shallow waters, it can eliminate bank access.</td>
<td>Thouvenot et al. 2013</td>
</tr>
<tr>
<td>8.3 Physical – water flow, power generation</td>
<td>(0-2) Score 2 for major nuisance, 1 for minor nuisance. Default = 0 if the species has not naturalized outside of its native range. If there is a reasonable amount of information about the species and it has naturalized outside of its native range, default = 0.</td>
<td>2</td>
<td>Impedes water flow in heavily infested areas.</td>
<td>EPPO 2011</td>
</tr>
<tr>
<td>8.4 Physical – irrigation, flood control</td>
<td>(0-2) Score 2 for major nuisance, 1 for minor nuisance. Default = 0 if the species has not naturalized outside of its native range. If there is a reasonable amount of information about the species and it has naturalized outside of its native range, default = 0.</td>
<td>2</td>
<td>Traps sediment and can clog irrigation canals and drainages.</td>
<td>EPPO 2011</td>
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<td>8.5 Aesthetic - visual, olfactory</td>
<td>(0-2) Score 2 for both visual and odor problems, 1 either, 0 neither or no mention of these impacts. Surface matting of macrophytes scores 1 for visual impact.</td>
<td>0</td>
<td>No odor problem; creates dense mats along the surface, but has attractive yellow flowers and shiny, dark leaves.</td>
<td>Meisler 2009; Kaufman and Kaufman 2013</td>
</tr>
<tr>
<td>9.1 Reduces biodiversity</td>
<td>(0, 1, 3, 5) Score 5 for extensive monospecific stands, 3 for species that become dominant, 1 for small monospecific stands, and 0 if species does not become dominant over other species. Default = 0 for this question if species has been in the trade globally for &gt;30 years and no information is found or if the species is not naturalized outside of its native range.</td>
<td>5</td>
<td>Forms extensive monospecific stands.</td>
<td>Thouvenot et al. 2013</td>
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<tr>
<td>9.2 Reduces water quality</td>
<td>(0, 1, 3) Score 3 if evidence that this species causes deoxygenation (e.g., through extensive growth in shallow water) or other water quality loss (e.g., loss of water clarity because of high decomposition rates continuously during the growing season), 1 if deoxygenation or other water quality loss is likely based on seasonal growth cycles (e.g., macrophyte that gets to high density and dies off at end of summer), 0 otherwise. Default = 0 for this question if species has been in the trade globally for &gt;30 years and no information is found or if the species is not naturalized outside of its native range.</td>
<td>1</td>
<td>Causes seasonal deoxygenation through extensive growth in shallows and decomposition.</td>
<td>Dandelot et al. 2005</td>
</tr>
<tr>
<td>9.3 Negatively affect physical processes</td>
<td>(0, 2) Score 2 if species alters hydrology (e.g., increases the chance of flooding) or substrate stability (e.g., increases amount of sediment erosion or deposition), or other physical processes, 0 if the species has no history of modifying physical processes. Default = 0 for this question if species has been in the trade globally for &gt;30 years and no information is found or if the species is not naturalized outside of its native range.</td>
<td>2</td>
<td>Increases chance of flooding; increases sedimentation.</td>
<td>Verdone 2004; Thouvenot et al. 2013</td>
</tr>
<tr>
<td>10.1 Human health impairment (e.g. drowning, poisonous, mosquito habitat)</td>
<td>(0-2) Score 1 for one effect, 2 for 2 or more effects.</td>
<td>1</td>
<td>Creates large areas of habitat for mosquito reproduction ideal for primary West Nile Virus vector species (Culex spp.); increased drowning risks possible, but unconfirmed.</td>
<td>Sears et al. 2006; Meisler 2009; CAST 2014</td>
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### Species: Uruguay waterprimrose; *Ludwigia hexapetala*

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<td>10.2 Weed of agriculture, including crops, livestock and aquaculture</td>
<td>(0-1) Score 1 if a problem agricultural weed, 0 if no evidence that it is an agricultural weed, or if evidence states that species is in agricultural areas but not problematic.</td>
<td>1</td>
<td>Does invade wet meadows and pastures. Unpalatable and low preference forage for cattle and horses. Similar species of <em>Ludwigia</em> is a major weed of rice crops in Asia.</td>
<td>Chauhan et al. 2011; EPPO 2011</td>
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<tr>
<td>11.1 Management - Ease of management implementation</td>
<td>(0-2) Score 2 if accessibility to weed is difficult, e.g. dense tall impenetrable growths or growing in habitats that are difficult to access by roads or waterways (e.g., swamps). For species that have naturalized outside of their native range, default = 0-2 based upon evidence about habitat and/or growth form if there is no direct evidence from the literature. Default = 0 if species has not naturalized outside of its native range and has been in the trade globally for &gt;30 years.</td>
<td>2</td>
<td>Growth is impenetrable when dense and occurs in water up to 3 m deep. Often grows in difficult-to-access areas (e.g., marshes, across channels).</td>
<td>Meisler 2009; Thouvenot et al. 2013</td>
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<tr>
<td>11.2 Management - Recognition of management problem</td>
<td>(0-1) Score 1 if difficult to assess weed, e.g., submerged; looks like another species. For species that have naturalized outside of their native range, default to a score between 0-1 based upon growth form evidence if there is no direct evidence from the literature. Default = 0 if species has not naturalized outside of its native range and has been in the trade globally for &gt;30 years.</td>
<td>1</td>
<td>Identification of <em>Ludwigia</em> species is very difficult. Some species of <em>Ludwigia</em> are native to the Delta.</td>
<td>DiTomaso et al. 2013</td>
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<td>11.3 Management - Scope of control methods</td>
<td>(0, 1, 2) Score 2 if no control method, 1 if only one control option. If species has naturalized outside of its native range, and there is no direct evidence for either 11.1 or 11.2, do not answer if there is no information. If there is direct evidence for 11.1 and/or 11.2, default to 0 if there is no information for this question. Default = 0 if species has not naturalized outside of its native range and has been in the trade globally for &gt;30 years.</td>
<td>0</td>
<td>Multiple control methods are possible (mechanical, chemical biological), but mechanical or chemical are currently the most viable options.</td>
<td>Meisler 2009; DiTomaso et al. 2013; Thouvenot et al. 2013</td>
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Species: Uruguay waterprimrose; *Ludwigia hexapetala*

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<td>11.4 Management - Control method suitability</td>
<td>(0-1) Score 1 if control method not always acceptable, e.g., grass carp, unregistered herbicide. If species has naturalized outside of its native range, and there is no direct evidence for either 11.1 or 11.2, do not answer if there is no information. If there is direct evidence for 11.1 and/or 11.2, default to 0 if there is no information for this question. Default = 0 if species has not naturalized outside of its native range and has been in the trade globally for &gt;30 years.</td>
<td>1</td>
<td>Not all herbicides are approved for aquatic use in California. Grass carp will consume <em>Ludwigia</em>, but prefer submersed plants and not viable option in Delta.</td>
<td>Pine and Anderson 1991; DiTomaso et al. 2013;</td>
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<tr>
<td>11.5 Management - Effectiveness of control</td>
<td>(0, 1, 2) Score 2 if ineffective, 1 if partial control. If species has naturalized outside of its native range, and there is no direct evidence for either 11.1 or 11.2, do not answer if there is no information. If there is direct evidence for 11.1 and/or 11.2, default to 0 if there is no information for this question. Default = 0 if species has not naturalized outside of its native range and has been in the trade globally for &gt;30 years.</td>
<td>1</td>
<td>Partial control possible over limited time periods of 1–3 years. Density is reduced more easily than area.</td>
<td>Meisler 2009</td>
</tr>
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<td>11.6 Management - Duration of control</td>
<td>(0, 1, 2) Score 2 if no control, 1 if control for 3+ months. If species has naturalized outside of its native range, and there is no direct evidence for either 11.1 or 11.2, do not answer if there is no information. If there is direct evidence for 11.1 and/or 11.2, default to 0 if there is no information for this question. Default = 0 if species has not naturalized outside of its native range and has been in the trade globally for &gt;30 years.</td>
<td>1</td>
<td>Partial control for 1–3 years.</td>
<td>Meisler 2009</td>
</tr>
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<td>12.1 Problem in other countries</td>
<td>(0, 1, 3, 4, 5) Score 5 if species has been reported to be a widespread problem (i.e., a harmful weed in many other countries), 4 if species has been reported to be a harmful weed in 5 or fewer countries, 3 if species has been reported to be a widespread adventive (but not a harmful weed) in many other countries, 1 if species has been reported to be adventive in 5 or fewer countries, 0 if not adventive elsewhere.</td>
<td>5</td>
<td><em>Ludwigia</em> is considered problematic in France, Ireland, Italy, Spain, Germany, Switzerland, the Netherlands, Great Britain, Belgium, Turkey, Australia, New Zealand, and Kenya.</td>
<td>EPPO 2011; Thouvenot et al. 2013</td>
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| USAqWRA Score | 76 |