APPENDIX G

PRESCRIPTIONS FOR THE CONTROL OF INVASIVE PLANT SPECIES AND NOXIOUS WEEDS

APPENDIX G:
PRESCRIPTIONS FOR THE CONTROL OF INVASIVE PLANT SPECIES AND NOXIOUS WEEDS

Invasive, non-native plant species are defined by the California Invasive Plants Council (Cal-IPC) as those that are not native to wildland ecosystems but can spread into them and displace or hybridize with native species, alter biological communities, and alter ecosystem processes. Invasive species are listed and rated as high, moderate, or low based on ecosystem impacts. Similarly, noxious weeds are defined by the California Food and Agriculture Code as any species of plant which is, or likely to be, detrimental or destructive to an ecosystem and difficult to eradicate. They are officially designated by the Director of Food and Agriculture and rated (A, B, C, etc.) by priority for control. For the purposes of the prescriptions provided in this report, those plants on the Cal-IPC list and not on the state list will be referred to as invasive plants. Those plants identified on the state noxious weed list will be referred to as noxious weeds. In this report, the use of the word "weeds" without other qualifiers will refer to both noxious and invasive weeds.

The Vegetation Management Program (VMP) included in this Wildfire Hazard Reduction and Resource Management Plan (WHR RM Plan) proposes to eradicate or control invasive and/or noxious weeds in treatment areas. The preferred approach is to work on a small set of species and to obtain control on those species before targeting a different set. The VMP specifies mapping of the locations where work is done to eradicate these invasive or noxious plant species. Test plots should be established to identify the efficacy of various control methods on targeted weeds. The control of weeds will comply with the East Bay Regional Park District's (EBRPD's) integrated pest management (IPM) policy, where the use of herbicides is minimized.

Weed control will use the principles of competitive autecology where treatment timing and type are matched to the growth stage of the plant to maximize the effect of the treatment. For example, disking, mowing, or grazing after yellow starthistle has bolted but before seed set is effective in reducing the present year's population along with reducing available seed for the next year's potential population.

The information provided in the following sections was compiled for the WHR RM Plan by LSA Associates, Inc., and Wildland Resource Management, Inc., from the following documents and online sources:

- EBRPD Pest Management Policies and Practices, Resolution #1987-11-325. Brownfield, N.T. and D. Sanders. 1987.
- Global Invasive Species Team. The Nature Conservancy and the University of California, Davis, 2008. http://tncweeds.ucdavis.edu/
- Invasive Plants. California Invasive Plant Council, 2008. www.cal-ipc.org

- *Invasive Plants of California's Wildlands.* Bossard, Carla C. , John M. Randal, Marc C. Hoshovsky, Ed., 2000.
- *Managing Himalayan Blackberry in Western Oregon Riparian Areas.* Bennet, Max, 2007.
- Natural Resource Project Inventory (NRPI). University of California, Davis and the California Biodiversity Council, 2008. www.ice.ucdavis.edu/nrpi
- Plants. National Invasive Species Information Center, 2008. http://www.invasivespeciesinfo.gov/plants/main.shtml
- Statewide Integrated Pest Management Program. University of California, Davis, 2008. http://www.ipm.ucdavis.edu/
- *Sycamore Grove and Veterans Regional Park Management Plan (Invasive Weed section).* Daar, S., 2006.
- *Training Marin Cows as Weed Managers*. Voth, K., 2006. http://www.livestockforlandscapes.com/
- *Using Fire as a Tool for Controlling Invasive Plants.* California Invasive Plant Council, 2006. www.cal-ipc.org/ip/management/fire.php#request
- *Vegetation Management Almanac for the East Bay Hills.* Hills Emergency Forum, 2007.
- Weed Eradication Program. California Department of Food and Agriculture, 2008. http://www.cdfa.ca.gov/phpps/ipc/weeds/weeds_hp.htm
- *Weed Workers Handbook: A Guide to Techniques for Removing Bay Area Invasive Plants.* California Invasive Plant Council, 2004. www.cal-ipc.org/ip/management/wwh/index.php
- *Yellow Starthistle Management Guide.* Di Tomaso, Joseph M., Guy B. Kyser and Michael J. Pitcairn, 2006. www.cal-ipc.org/ip/management/yst.php

Management Strategies

The goal of this Plan's vegetation management program is to work toward an ecosystem that is in equilibrium with a diverse and competitive mosaic of vegetation types that are sustainable for given site parameters. In keeping with the Plan's goal, the following are three objectives that implemented vegetation management strategies should seek to address (with special emphasis, where feasible, on invasive and noxious weeds principally found in EBRPD fuel breaks):

1. Controlling weeds.

2. Achieving land use objectives such as wildland fuel reduction, wildlife habitat maintenance, ecosystem preservation, forage production, or recreational land management.

3. Preventing reinvasion of the targeted weed or invasion of other noxious species.

An understanding of the biology and ecology of the target species is necessary for long-term management. It is also important to be familiar with the following characteristics of the ecosystem:

- Other species present (both weeds and desirable plants),

- Potential for invasion into un-infested sites in the area,
- Impact of the management strategy on sensitive species and habitats, and
- Ecosystem parameters such as soil conditions, ecological (rangeland) sites, and hydrologic features.

Funding limitations may require prioritizing areas of greatest concern. At a minimum, the budget for weed control activities should consider:

- Direct costs (such as labor, equipment, and follow-up management activities)
- Indirect costs (such as the risk of treatment failure, non-use of target areas during establishment periods)
- Potential benefits from treatment actions
- Potential risks from treatment actions
- Staff training in the safe application of herbicides
- Public outreach information on vegetation management projects
- Written pest control recommendations.

Annual monitoring and evaluation should be conducted to determine the adequacy of the treatment techniques and management approach. Long-term commitment of three or more years is typically necessary to ensure treatment success. Follow-up treatments are usually necessary to prevent re-infestation or the occurrence of substitute invasive species. The Plan's management strategies should be implemented in compliance with the EBRPD Pest Management Policies and Practices Resolution.

Working with Sensitive Species/Communities:

When there are sensitive species or communities present, the following two key components should be added to the management strategy:

1. Identify sensitive species/community habitat requirements and work within those requirements. For example, avoid breeding/flowering seasons, maintain a certain vegetation structure necessary for survival, or remove sprouting plant species and leave obligate seeding species.

2. Identify known impacts to and avoid or lessen the potential for those impacts on sensitive species. Sensitive species identified in RTAs are included in Table VI.3 of this Plan.

TREATMENT OPTIONS

Tables G.1 and G.2 provide a summary of treatment options for various woody and herbaceous invasive species and noxious weeds found in the East Bay Hills, respectively. The effectiveness of various treatment methods are tied to multiple factors, including:

- Environmental conditions, such as wet or dry periods.

- Species reproduction and growth patterns, such as persistence of seed bank, ability to resprout or vegetatively reproduce.
- Growing cycle of individual plants, including active growing period, blooming, before seed set, and periods of decline.
- Size and age of colony population.

Tables G.3 and G.4 provide treatment timing calendars for selected woody and herbaceous invasive species, respectively. More detail regarding specific treatment options is provided in Sections B, C, and D of this report.

Hand Labor Treatment

Hand labor treatment includes methods such as pulling, digging, scraping, cutting, girdling, frilling or drilling the cambium layer of woody species, or weed whipping grassy species, and is mostly appropriate for small weed infestations at the backyard garden scale. Although volunteer efforts incorporating hand labor treatment have been used with some effectiveness for some species, maintaining these efforts at the landscape scale and for a sustained duration has proven difficult. The Bradley Method is one sensible approach to manual control of weeds, which consists of hand weeding selected small areas of infestation in a specific sequence, starting with the best stands of native vegetation (those with the least extent of weed infestation) and working towards those stands with the worst weed infestation.[1] As the native plants stabilize in each cleared area, the work should move deeper into the center of the most dense weed patches.

Mechanical Treatment

Mechanical treatments use mechanized equipment to remove above ground vegetation and include mowing and brush cutting, as well as the use of chainsaws, grinders, backhoes, or bulldozers. These methods are often nonselective in that all vegetation on a treated site is affected. Mechanical treatments are highly effective for controlling woody vegetation on gentle topography with few obstacles such as rocks, stumps, or logs. However, most mechanical equipment is not safe to operate on slopes over 30 percent. It is also of limited use where soils are highly susceptible to compaction or erosion or where excessive soil moisture is present.

Various attachments are available for bulldozers and tractors to clear and uproot woody plants. Brush rakes or blades may be mounted on the front of the bulldozer or root plows may be pulled behind. These techniques result in varying degrees of soil disturbance and may create erosion problems. Brush rakes displace less soil than a straight blade and are much faster at removing brush.

Grazing

Cattle, goats, and sheep can often negotiate slopes too steep to manage with mechanical treatments and they do not pose the same level of potential environmental risk as herbicides. Since goats trample or browse virtually all vegetation within a fenced area, however, any desirable trees or shrubs should be protected with lightweight flexible fencing.

In addition to their value for weed control, sheep can also be used for income from the sale of their wool and cattle from their sale for meat. It is possible; however, that seed re-introduction may occur

[1] Fuller, T.C. and G.D. Barbe, 1985. *The Bradley Method of Eliminating Exotic Plants from Natural Reserves.* July.

from animal droppings. Grazing by animals may also cause soil disturbances. An additional disadvantage associated with using livestock is that they may impact desirable species through grazing (if palatable) or trampling.

Prescribed Burning

Prescribed burning can include controlled broadcast burns to cover large areas or pile burns to remove cut debris. The California Invasive Plant Council has published a manual on the use of fire as a tool for controlling invasive plants that should be referred to for further information than that provided here.

Table G.1 Summary of Treatment Options for Invasive Woody Plants in EBPRD Treatment Areas

Scientific Name	Common Name	Type	Reproduction	Stump/Stem Resprout	Optional Control Methods					
					Manual	Mechanical	Grazing	Prescribed Fire/Flaming	Biological	Chemical
Acacia melanoxylon	Blackwood acacia	Tree	Seed and vegetative	Yes	Yes	Yes	Yes	No	No	Yes
Eucalyptus globulu/s E. camaldulensis	Blue gum/Red gum	Tree	Seed and vegetative	Yes	Yes	Yes*	No	Yes (seedlings)	No	Yes*
Genista monspessulana, Spartium junceum, Cytisus scopariuls	French, Spanish, Scotch broom	Shrub	Seed	Yes	Yes	Yes	Yes	Yes	No	Yes
Pinus radiata	Monterey pine	Tree	Seed	No	Yes	Yes	No	Yes	No	Yes
Rubus discolor	Himalaya blackberry	Shrub	Seed and vegetative	Yes	Yes	Yes	Yes	No	No	Yes

*Partially effective or used in conjunction with other methods.
Source: LSA Associates Inc., 2008.

Biological Control

Biological control refers to the use of insects or pathogens to control weeds. The introduction of exotic natural enemies to control plants is a complex process and must be thoroughly researched before implementation to prevent unintended biological or agricultural impacts. Such tools are not normally suitable for preserve managers to implement.

Biological control does not aim to eradicate weeds but to keep them at low, manageable levels. After their introduction, biological control agents can take 5 to 10 years to become established and increase to numbers large enough to reduce the density of the target weed. Once established, effective biological controls provide an inexpensive, long-term, and non-toxic means to control weed populations. Since insects have specific requirements for growing and thriving, however, it is important to match the insect to the weed management site. Understanding these requirements will help integrate the insects into other weed control efforts. When biological controls are released, other

control methods should be used on the perimeter of the release site, but avoided where they might adversely impact the insect population.

Herbicides

In IPM programs, herbicides are considered transitional tools that enable the manager to suppress weeds and replace them with desirable, competitive vegetation. Thus it is important to select the least-toxic, low-residual herbicide that is effective against the target weed, and to apply it in a judicious manner using spot treatments rather than broadcast application.

There are several techniques for applying herbicide; all require training and supervision by a licensed applicator. Techniques include cut-stump treatment, foliar spray, and low-volume basal bark application. Herbicides can also damage desirable native plants and animal species, and consequently are not appropriate for some infested sites, especially those near water. An herbicide table for California-registered herbicides is available in the appendix of the *Invasive Plants of California's Wildlands*. The use of herbicides should be limited to those approved for use on EBRPD lands as specified in the EBRPD Pest Management Policies and Practices Resolution.

Table G.2 Summary of Treatment Options for Invasive Herbaceous Plants in EBPRD Treatment Areas

					Optional Control Methods					
Scientific Name	**Common Name**	**Type**	**Reproduction**	**Stump/Stem Resprout**	**Manual**	**Mechanical**	**Grazing**	**Prescribed Fire/Flaming**	**Biological**	**Chemical**
Carduus pycnocephalus	Italian thistle	Annual herb	Seed	Yes	Yes	No	Yes	No	No	Yes
Centaurea calcitrapa	Purple starthistle	Biennial Herb	Seed	Yes	Yes	No	No	No	No	Yes
Centaururea solstitialis	Yellow star thistle	Annual herb	Seed	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cirsium vulgare	Bull thistle	Biennial herb	Seed	Yes	Yes	Yes	No	No	Yes	Yes
Conium maculatum	Poison hemlock	Biennial herb	Seed	Some	Yes	Yes	No	No	No	Yes
Cortaderia selloana, C. jubatum, Cortaderia jubata grass	Pampas grass	Perennial grass	Seed and vegetative	Yes	Yes	No	Yes?	No*	No	Yes
Cynara cardunculus	Artichoke thistle	Perennial herb	Seed	Yes	Yes	No	No	No	No	Yes
Delairia odorata	Cape ivy	Perennial vine	Vegetative	Yes	Yes	No	No	No	No	Yes
Euphorbia oblangata	Oblong spurge	Perennial herb	Seed	Yes	Yes	No	No	No	No	No
Phalaris aquatica	Harding grass	Perennial grass	Vegetative, seed	Yes	Yes	Yes	Yes	Yes	No	Yes
Silybum marianum	Milk thistle	Anuual /biennial herb	Seed	No	Yes	Yes	No	No	No	Yes

Source: LSA Associates Inc., 2008.

Revegetation

Planting of native or other desirable vegetation to compete with invasive plants and help prevent spread by providing a ground cover is an essential part of a long-term control program. Applications of mulch after weed removal, with or without new vegetation plantings, can also be effective in minimizing re-invasion. Virtually all weed control efforts should be followed by revegetation to control erosion and to help minimize re-infestation with a competitive vegetative cover.

Table G.3: Resource Considerations Treatment Calendar for Woody Invasive Plants

Plant	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
French Broom	1	1	1	1	2	2	3	3				
Spanish Broom				1	1	2	3	3				
Acacia		1	1	1	1	1	3	3	3			
Blackberry				3	3	3	1	1	1			
Eucalyptus	1	1	3	3	3	3	3	3	3	3		1
Pine[a]			3	3	3	3	3	3	3	3		

1 = Conduct treatments during this time to avoid spreading seed. Treatment most likely to control pest plant late in this season, closer to seed set.

2 = Use caution; treatments may spread seed if not contained

3 = Use extreme caution or avoid treatments; seed spread likely if not contained

[a] Professional judgment regarding seed spread based on flowering period (Munz and Keck 1959) as no data available from the Vegetation Almanac (Danielsen et. al 2000).

Sources: Danielsen, C., R. McClure, E. Leong, M. Kelley, and C. Rice. 2000. Vegetation Almanac for the East Bay Hills. Hills Emergency Forum, Berkeley CA. Munz, P.A. and D.D. Keck. 1959. A California Flora. University of California Press. Berkeley and Los Angeles CA.

Table G.4: Resource Considerations Treatment Calendar for Selected Herbaceous Invasive Plants

Plant	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Yellow Starthistle					1	1	1	3	3	3		
Hemlock				1	1	3	3	3				
Spurge			1	1	1	1	2	2				
Fennel					1	1	1	1	3	3		
Milk Thistle					1	1	3	3	3			

1 = Conduct treatments during this time to avoid spreading seed. Treatment most likely to control pest plant late in this season, closer to seed set.

2 = Use caution; treatments may spread seed if not contained

3 = Use extreme caution or avoid treatments; seed spread likely if not contained

Sources: Danielsen, C., R. McClure, E. Leong, M. Kelley, and C. Rice. 2000. Vegetation Almanac for the East Bay Hills. Hills Emergency Forum, Berkeley CA. Munz, P.A. and D.D. Keck. 1959. A California Flora. University of California Press. Berkeley and Los Angeles CA.

GENERAL WEED CONTROL MEASURES

The following weed control measures should be considered, at a minimum, for any potential treatment action on EBRPD lands:

Planning Phase

- Encourage certified weed-free seeds where feasible and cost-effective. The State has begun to certify weed free hay; however, no inspectors were funded by the California Department of Food and Agriculture (CDFA).
- Communicate with adjacent private property owners and public agencies through the Weed Management Area Work Group about target weed species, infestation levels, and control practices. Early detection and treatment can prevent small satellite populations from expanding into a large extensive infestation. Cooperation in adopting similar prevention practices, such as buying weed-free hay for feed and erosion control from reputable growers and dealers, can reduce the spread of weeds into surrounding properties.

Pre-Implementation Phase

- Encourage enclosure-style high intensity grazing in those areas heavily infested with invasive weed species before they flower and set seed. Grazing after seed set should be followed by a quarantine of the animals onsite for 7 to 14 days before moving them to a non-infested site. If this is not practical, contain animals for 7 to 14 days in a holding area before moving them to non-infested areas. Amend the grazing plan to encourage this intensive controlled grazing.

Implementation Phase

- Thoroughly clean the undercarriages of all vehicles and machinery entering the vegetation management area. Inform construction companies entering the area that vehicles must be cleaned before entering. Many construction companies have weed control measures and can steam clean the underside of machinery.
- Minimize soil disturbance caused by water, livestock, vehicles, or machinery, including graders.
- Observe good land management practices such as deferred or rotational grazing; water conservation; erosion control; proper fertilization; re-seeding to maintain dense, hardy grass cover; revegetation; and maintenance of competitive vegetation that can withstand weed invasion. Because most noxious weeds are pioneer species, a dense ground cover of desirable plants with a closed canopy will usually help prevent their establishment.

Post-Implementation Phase

- Monitor vigilantly and eradicate small new infestations, especially in areas of new disturbance.

The following sections provide species-specific treatment information and prescriptions. Additional information for each species can be found in the source documents and online resources identified earlier in this report.

WOODY INVASIVE PLANTS

ACACIA (*Acacia melanoxylon)*

Growth Characteristics

A native of Australia, Blackwood acacia can grow as individual trees up to 40 feet tall. Unlike many acacias, Blackwood acacia does not retain its pinnate leaves; they are replaced by oblong phyllods

which are actually expanded leaf stocks. It is a moderately fast growing tree. Other acacia species can grow as evergreen shrubs in dense thickets.

Reproduction Characteristics

In addition to being a significant fire hazard, acacia can successfully out-compete native plants. Blackwood acacia can reproduce by both creeping roots or by seeds and will resprout from cut stumps. Seeds are easily germinated, apparently long-lived, and copious seed production can be responsible for its invasiveness. Acacia is also apparently fire-stimulated, with prolific regeneration from seed and sprouts after fire.

Control Strategies/Prescriptions

Management efforts must be very long-term in scope in order to be successful, due to the apparent longevity of buried seeds.

Hand Labor Treatment: The flowers of acacia are extremely allergenic, so manual control should be done using protective gear. Hand digging, pulling, and hoeing are not feasible because of mature acacia's deep-rooted and woody characteristics. However, seedlings of acacia can be hand-pulled before roots are well-established. Manually-operated tools such as brush cutters, power saws, axes, machetes, loppers, and clippers can be used to cut acacia but are only marginally effective if used alone, as the remaining roots will resprout. However, cutting can be effective in combination with other treatments as it removes the above-ground portion of the plant. Cutting should be done after flowering but prior to seed set to prevent seed production and dispersal. Repeated cuttings may help to exhaust the reserve food supplies in roots. Cutting after flowering is effective because the reserve food supply is nearly exhausted, and new seeds have not yet been produced. After cutting or chopping with mechanical equipment, acacia resprouts from root crowns in greater density if not treated with herbicides.

Mechanical Control: Acacia may be trimmed back by tractor mounted cutters on even ground. The same precautions, timing and follow-up should be used as described above for Hand Labor Treatment.

Grazing: Goat grazing is effective in controlling smaller plants.

Prescribed Burning: Broadcast burning is probably not a practical tool for control of acacia because of the risk of escape due to high woody fuel loads.

Biological Control: There are no USDA-approved insects for biological control of acacia.

Chemical Control: Foliar herbicides in the pyridine group have been effective in treating acacia when applied to the foliage of seedlings or sprouts when actively growing. Herbicide treatment is most effective after mechanical removal of large plants.

BROOM (*Cytisus scoparius, Spartium junceum, Genista monspessulana*)

Growth Characteristics

Scotch broom (*Cytisus scoparius*), Spanish broom (*Spartium junceum*) and French broom (*Genista monspessulana*), share similar biology, growth-habits, and life cycles. Since control measures are also similar, they will be considered as one group unless otherwise noted.

Scot's or Scotch broom is loosely branched with green, slender ribbed branches and small, simple leaves up to half an inch long. It grows from 3 to 10 feet in height. The bright yellow flowers are pea-like, about three-quarters of an inch long. Its seed is borne in dark brown to black hairy, flattened pea-like pods, which when ripe, burst and scatter seeds for yards. It is often confused with Spanish broom which looks similar but is easily distinguished by its rounded, bright green stems, fragrant blossoms, and later flowering time.

Spanish broom is an erect, green-stemmed, almost leafless shrub growing to as tall as 9 feet. The alternate to subopposite leaves are few, and when present are simple, entire-margined and small, from 1/2 to 1 inch long. They are linear-lanceolate in shape, glabrous on the upper surface and appressed-hairy below. The bright yellow flowers are large and showy in long open terminal racemes, papilionaceous, fragrant with petals 3/4 to 1 inch long. The calyx is split above almost to the base with five minute teeth. There are ten stamens with filaments fused around the pistil. The fruit is a linear pod 2 to 4 inches long, dehisecent and many-seeded, and with or without strigose. It blooms from April to June.

French broom is a perennial alternate-leaved shrub growing to 10 feet tall with villous branchlets and trifoliate, oblanceolate to obovate leaves. The flowers are in clusters of 4 to 10 on short, axillary stems, and have a silky-hairy, three-pointed calyx and bright yellow petals with a glabrous, ovate banner to 1/2-inch long. The 10 stamens are fused into a tube about halfway along their length. The fruit is a densely villous seedpod about one inch long. French broom blooms from March to May.

Reproductive Characteristics

Brooms spread primarily by seed dispersion and the seeds are viable in soil from 5 to 60 years. When mature the seedpods suddenly split and eject seeds up to 20 feet away. Broom seeds can be further dispersed by ants collecting the seeds and by water. Over 10,000 seeds can be produced per plant. Scotch broom flowers from March to June. Seeds are produced in late summer. Spanish broom flowers from July to early frost. Seeds are produced in August through September, and it resprouts readily from the root crown after cutting, freezing, and sometimes after fire.

Control Strategies/Prescriptions

Integrated Approach: Control measures must address both removal of standing plants and eventual depletion of the seed bank. Cutting French broom when it is first in flower may help reduce the seed supply that year. A woody tap root makes plants relatively easy to pull, especially when the soil is moist. It is very rewarding to pull hundreds in an hour, clearing a small area of seedlings. Because broom can resprout from root crowns, repeated treatments may be needed to exhaust root reserves. Older plants may not re-sprout after cutting, although younger plants do. To reduce resprouting, broom may be mowed in late summer when soils are dry.

Some land managers contend that seeds in the soil will never be depleted if stands are over seven years old, but treatment may be successful in younger stands. The most effective removal treatment in a project in Eldorado Forest in the Sierra Nevada foothills was found to be cutting shrubs in September and October, allowing cut shrubs to dry on site, and then burning dried shrubs in late May and early June. This killed any resprouts and most of the seed within the top one inch (2 cm) of the

soil. Seeds within 1.6 inches (4 cm) of the surface were scarified by heat, germinated within two weeks, and died during the summer drought period. This reduced the amount of seed in the soil by 97 percent. Although some seed remained below 2 inches (6 cm) in ant nests, the reduction in the seedbank significantly decreased the need for chemical or hand removal of new seedlings in succeeding years. Follow-up monitoring and treatment using this same combination of methods in a coastal area of Redwood National Park reduced the seedbank by only 52 percent and did not significantly reduce the time spent in follow-up control. The moister climate decreased the efficacy of this removal combination at the Redwood National Park site. Because of broom's seedbank, monitoring removal sites to locate and kill new seedlings is essential. Location and retreatment of resprouts is also imperative. If any single removal technique is used the site should be examined once a year, when seed germination ends in late spring, for 5 to 10 years. Using the combined removal treatments, monitoring should occur late spring, yearly, for the first two years then again the fourth and sixth year after removal.

Hand Labor Treatment: Hand pulling is best done on small stands of broom. When beginning a hand labor treatment, flag the treated areas so they can be identified for follow-up in subsequent seasons. When faced with dense and/or extensive stands of broom, it is best to divide them into grids (with flags, stakes, etc.) so that workers can thoroughly weed smaller areas before moving onto the next grid. The grid system also facilitates dividing work activities between those pulling and those removing the debris.

Hand pulling destroys young plants and seedlings, but for larger, mature plants, use a specialized tool called a "weed wrench." This hand-operated tool acts as a lever to pull the entire plant out, including roots, so that resprouting does not occur. Various sizes of the tool are available to suit different size plants. To minimize disturbance on steep hillsides, remove plants in the spring when soils are moist. A claw mattock can be used for plants up to 13 ft tall. After the soil around the root is loosened, the claw is used to pull out the plant in the same way a claw hammer is used to pull out nails. However, the resultant soil disturbance tends to increase the depth of the seedbank. Wrench removal is labor-intensive, but can be used in most kinds of terrain and allows targeting of broom plants with low impact on desirable species in the area. Golden Gate National Park has had success in using volunteers to remove broom with weed wrenches and then closely monitoring and removing broom seedlings for five to ten years.

Hand hoeing can readily destroy seedlings and young plants, either by cutting off their tops or by stirring the surface soil to expose the seedlings to the drying effects of the sun. The object of hoeing is to cut off weeds without going too deeply into the ground and doing damage to the roots of desirable vegetation. Older broom plants with a large tap root can resprout after hoeing.

Cutting can be employed where broom infestations are difficult and dangerous to pull, especially where footing is uncertain. Cutting is an alternative that minimizes soil disturbance and involves tools such as brush cutters, power saws, axes, machetes, hand pruners, loppers, and clippers. Roots remain intact and are helpful in stabilizing soil on steep terrain.

Cut stems close to the ground under maximum drought conditions to reduce its ability to resprout. The effectiveness of cutting depends on stem diameter, time of cut, and the age of the plant. For scotch broom, its ability to resprout declines with age. Cutting plants low during dry months (late July and August usually after flowering) can kill broom, whereas cutting prior to flowering, although

effective in preventing another seed crop, may result in resprouts and little mortality. Avoid cutting shrubs during the rainy season (December to March) when resprouting is highest. When resources are limited, resources should be concentrated on larger, mature, seed-producing broom first, before spending time on younger plants.

Saw cutting removes above-ground portions of shrubs, but depending on the time of cutting, may result in high rates of resprouting. In the Sierra Nevada foothills saw cutting undertaken at the end of the summer drought period (August to October) resulted in a resprouting rate of less than 7 percent, whereas cutting done at other times resulted in resprouting rates of 40 to 100 percent. In British Columbia plants greater than one-quarter inch (3 mm) in diameter cut below two inches (5 cm) from the soil surface in July were found to have less than 1.5 percent resprout rate.

Mechanical Treatment: Mowing can be done with tractor-mounted mowers on even ground, or by scythes on rough or stony ground. Keep in mind that most large mechanical equipment is not safe to operate on slopes over 30 percent and should not be used in areas sensitive to soil compaction or erosion.

The following is an effective mechanical approach to control broom:

- Cut broom at or below ground level in late July or September, after broom has set seed and when soil moisture is at its lowest. This will increase mortality of adult plants and decrease resprouting because nutrient reserves are at their lowest. The warm, cleared soil will stimulate seedling germination and repeated cutting will gradually deplete the seedbank. For broom with a one-inch diameter, a heavy-duty gasoline-powered brush-cutter with a four-point metal blade can be used to cut through stalks effectively.[2] For stems greater than one inch in diameter, use a brush-cutter with an 80-toothed blade or forest clearing blade.
- Clear the broom from the site, or stack debris into piles, to increase light penetrance to the soil. This will flush out seedlings, reduce the seedbank, and allow easier access for follow-up treatments.
- Mow seedlings the following summer using a brush-cutter with a three-point metal blade, after grasses have set seed. At this stage, seedlings are still vulnerable and can be killed by cutting the stems at or below the root crown. Seedlings will be roughly 6 inches tall and can be left where cut.
- Repeat treatment for subsequent years until the seedbank is depleted.

Brush hogs, which twist off above-ground biomass, can be used for broom removal. They are less labor-intensive, but like other Mechanical treatments heavily impact non-target species and cannot be used on steep slopes. The twisting action is more destructive to tissues that initiate resprouting than is clean cutting. However, depending on the season of brush hog removal, resprouting can still be a serious problem.

Grazing: Broom is slightly toxic and somewhat unpalatable to most livestock. Goats and sheep graze of the tops of young plants, preventing plant development, seed formation, and gradually depleting

[2] Archibald, G. 1996. A French broom control method. *CalEPPC News* 4(3): 4-6.

root reserves. Grazing, or other management methods, must continue until the seed bank is eliminated.

If confined, Angora and Spanish goats will feed on broom. Goats are most cost-effective when used to clear one- to four-year-old regrowth rather than the initial clearing of dense, mature stands. When faced with mature brush, goats defoliate twigs and strip off bark, but do not touch the plants' main branches, which are too tough to eat. Chickens can be used in areas that have been cleared of mature broom stands to deplete the seed source.

Prescribed Burning: Controlled burning is effective in reducing the seed bank and can be used to treat dense monocultures. Fire kills mature stands of broom and stimulates seedling germination. If areas are burned in the summer, seedlings that emerge after the burn are exposed to the harsh, dry environment, increasing seedling mortality. Allow some time for the drying action of the sun to kill seedlings. Follow-up treatments for controlled burns include subsequent controlled burns, grazing, hand pulling, and revegetation with fast growing native species.

Re-burn of the removal site is usually necessary two and four years after the initial burn. Repeated burning of cut broom has been used to control broom in Marin County, California. Broom stems were cut in the fall and burned in the spring when weather conditions were more favorable. The cut debris was left on the site to provide fuel for the burn. After the initial burn, sterile plants were planted to prevent broom re-establishment and to provide the necessary fuel source for subsequent burns. Even though these plants provided a small, patchy amount of fuel, the following burn killed broom seedlings and resprouts, and also stimulated native vegetation that is adapted to fire. At present it is unclear how many subsequent burns are required to deplete the long-lasting seed bank; however, dramatic reductions of broom densities after 3 burns have been observed. Like many weed species, long-term treatments are necessary. A flame thrower or a weed burner device can also be used as a spot treatment to heat-girdle the lower stems of broom.

Biological Control: Two USDA approved insects, a stem miner, *Leucoptera spartifoliella,* and a seed beetle, *Apion fusciostre*, were introduced in the 1960s as biological control agents, but have had limited success in California. New insect biological control agents are being tested in England and France for use on broom in Australia and New Zealand. If proved safe and effective in California, these insects may ultimately become available for use as biological control agents in California.

Studies in New Zealand have identified the fungal pathogens *Pleioshaeta setosa* on broom and *Fusarium tumidum* on broom and gorse plants. More studies are necessary before these pathogens can be released, and no attempts have been made to study the effects of these pathogens in the U.S.

Chemical Treatment: Foliar spraying with 2 percent glyphosate (as Roundup®) has been used to kill mature plants of Scotch broom. Adding surfactant improves effectiveness. The foliar spray impacts non-target species and resprouting may occur. Triclopyr ester (25 percent) (as Garlon®) in Hasten® or Penevator®, or other seed press oil (75 percent) applied with a directed hand application in low volume (2-3 drops) to basal bark has also proved effective. This application technique does not affect non-target species, but it is more time-consuming and may be impractical for large infestations. Both of these chemical methods should be used during periods of active growth after flower formation. Chemical removal alone results in standing dead bio-mass that makes monitoring for and treatment of broom seedlings difficult. The standing dead biomass also presents a major fire hazard.

EUCALYPTUS (*Eucalyptus globulus/ E. camaldulensis*)

Growth Characteristics

Bluegum eucalyptus (*Eucalyptus globulus*) is an introduced, aromatic tree that generally grows from 98 to 180 feet tall, often in dense monocultures. Its thick, waxy adult leaves hang vertically and are grayish-blue, narrow lanceolate or sickle-shaped, and four to eleven inches long. Bark shreds prodigiously from the trunk, building up into a dense litter layer. Red gum (*E. camaldulensis*) is an introduced aromatic tree that can grow up to 75 feet tall. It is similar to blue gum in having thick waxy leaves and shredding bark but with thinly lanceolate leaves. Other characteristics and control techniques are similar between the two species.

Reproductive Characteristics

Flowering of both species occurs beginning when trees mature at four to five years of age. Flowers develop from November to April in California with pollination by insects and hummingbirds. Fruit and seed ripen from October to March about 11 months after flowering. Capsules open immediately on ripening, and the seed is dispersed by wind up to 60 feet or more. Newly released seeds germinate within a few weeks under suitable conditions. Germination rates range from 2 to 80 percent within a 30-day germination period. Soil-stored seed under older stands often germinates prolifically following fire, logging, drought or other disturbance. Seedlings often survive in sufficient abundance to significantly invade neighboring plant communities. Establishment of eucalyptus saplings within groves is inhibited by forest litter and duff, but can be significant following disturbances such as fire or logging operations.

Eucalyptus has a prodigious ability to sprout in response to damage by fire, logging, or other disturbances. They can sprout from the trunk (stem), from stumps of all sizes and ages, from the lignotuber (a woody swelling at the base of the stem, partly or wholly underground), and from the regular roots. Eucalyptus also reproduces by stem layering.

Beneath the bark of many eucalyptus species are specialized epicormic buds that lie dormant until the canopy of the tree is either removed or scorched by fire. The loss of leaves triggers a burst of growth from these buds (epicormic shoots), which provide an almost immediate growth of leaves to sustain life and aid the recovery of the plant. Eucalyptus trunks clothed in fresh, green foliage are a common sight after a wildfire.

Most eucalyptus trees have a specialized root system called a lignotuber. The lignotuber is visible in young saplings, becoming buried as the plant increases in size. The lignotuber contains adventitious buds from which new shoots develop if the top of the plant is cut off or burnt. It also contains food reserves. This specialized root is protected by the soil surface from damage from fire. Most soils are poor conductors of heat and provide adequate protection to lignotubers. As with epicormic buds, lignotuber buds respond when the upper part of the tree is damaged by fire or sustains wounds to the stems. The lignotuber can live for many years in the soil after stems die back, and can regenerate growth of the tree if not destroyed.

Blue gum and red gum eucalyptus generally do not form a taproot; rather, they produce roots

throughout the soil profile, rooting several feet deep in soils that permit it, or shallowly otherwise. On most trees all the roots are below the lignotuber, but occasionally adventitious roots result from layering of the stem above the lignotuber.

Control Strategies/Prescriptions

Eradication of problem eucalyptus trees requires prevention or control of re-sprouts and seedling suppression. Sprouting is dependent on food reserves stored in the lignotuber and root system. Seedlings are likely to emerge after hade intolerant seeds are exposed to sunlight after tree removal.

Hand Labor Treatment: Seedlings can be hand-pulled or grubbed out with a hoe, pick, or Pulaski tool, but these actions will need to be repeated several times during the first season after tree removal to eliminate flushes of seed germination. To prevent erosion from soil disturbance, mulch should be applied until desirable vegetation has become established. Eucalyptus is highly intolerant of shade, so the mulch will also suppress seed germination. Re-sprouts can be manually removed with loppers or machetes. Persistent removal of sprouts will eventually kill the stump as food reserves in the roots are exhausted. This method is not practical for large stands with hundreds of trees unless a large labor force is available.

Mechanical Treatment: Because of the large size and height of mature eucalyptus trees, felling with chain saws is the only practical mechanical control. Seedlings, saplings, and resprouts can be trimmed back using tractor mounted mowers. After trees are felled and removed, small stumps can be pulled out with a vehicle and winch. Large stumps can be pushed out with a tractor/dozer with an attached blade. Large stumps can also be cut level with the soil and ground down with a mechanical stump grinder. To prevent sprouting from the lignotuber or roots, the stump must be removed to a depth of 18 to 24 inches. The cavity in the stump created during the grinding process should be filled and capped off with soil to stimulate decomposition by microorganisms and block sunlight to ensure against resprouting.

Grazing: Blue gum eucalyptus foliage is unpalatable to cattle, sheep, and goats, so grazing does not appear to be a viable management option for control of sprouts or seedlings.

Flaming: A propane-fueled weed burning device can be used as a spot treatment to heat-girdle the lower stems of small trees and re-sprouts. Use of the green flamer in late summer could constitute a fire hazard, so the presence of a water truck or other water source is essential if this method is to be used in the dry season. Research is needed to thoroughly test the use of flaming on re-sprouts during various seasons of the year. If this method does prove safe to use and is effective against re-sprouts, it would have the additional advantage of causing minimal general disturbance to the surrounding environment during and after treatment.

Prescribed Burning: Prescribed fires are used to control seedlings and reduce ground litter under mature trees. Spring fires have reduced fuel loads up to 87 to 96 percent without damage to overstory trees. Prescribed burning has been widely applied to eucalyptus forests in Australia to reduce fuel loads and prevent wildfires.

Chemical Treatment: The most effective method of controlling resprouting is to apply glyphosate (Round-Up® or Aquamaster®) or triclopyr (Garlon®) to the outer portion of the stump's cut surface immediately after felling. Triclopyr should be applied at the rate of 80% in an oil carrier and

glyphosate should be applied at 100%. The most effective control is achieved when cutting in the fall. Follow-up treatments of resprouts with foliar applications of triclopyr or glyphosate in 2% solutions are usually necessary for complete control.

Revegetation: Following eucalyptus removal the site should be revegetated with desirable species capable of competing against eucalyptus sprouts or seedlings. The least intensive method is to encourage natural colonization of vegetation from adjacent areas. Temporary mulch can be used to cover the bare soil prior to revegetation. EBRPD has noted favorable results by grass seeding and installing mulch fabric for erosion control during the first winter after eucalyptus removal, followed by control of thistles and other herbaceous invasive plants during the first few years following treatment.

HIMALAYAN BLACKBERRY (*Rubus discolor)*

Growth Characteristics

Himalayan blackberry is a robust, evergreen shrub up to 10 feet tall and canes as long as 23 feet long. It forms large root crowns or burls with roots as deep as 35 inches and as long as 34 feet. Canes are biennial, developing from buds at ground level the first year and growing from first year canes the second year when spines develop. Canes die after the second year, forming an impenetrable thicket. Himalayan blackberry cannot tolerate dense shade and rarely occurs in dense forests, except in openings.

Reproductive Characteristics

Himalayan blackberry produces vast numbers of seeds (up to 13,000 per acre) which are spread via their fruits by animals and humans as they are highly palatable. Seeds remain viable in the soil for several years. Himalayan blackberry also reproduces vigorously by vegetative means. It sprouts readily from root fragments and stem cuttings. Canes root at the tips and the nodes. A single cane cutting can produce a thicket 16 feet in diameter in two years.

Control Strategies/Prescriptions

The best approach to control Himalayan blackberry includes the following steps:

1. Site preparation that removes most of the aboveground biomass;
2. Removing or killing root crowns and roots;
3. Planting an seeding native vegetation to discourage re-colonization; and
4. Conduct maintenance to favor establishment of native or desirable vegetation.

The most effective techniques use a combination of mowing or cutting with herbicide treatments. One approach is to allow Himalaya blackberry to resprout and grow 18 inches tall before spraying the sprouts with triclopyr or glyphosate, preferable from September through November. Another approach is to broadcast herbicide in late summer or fall before cutting or burning.

Hand Labor Treatment: Root crowns and roots can be dug up using a Pulaski tool or mattock after initial mowing or cutting. This method is very strenuous and creates high levels of soil disturbance.

Mechanical Treatment: A backhoe with an opposable thumb or mechanical claw can be used to grab and uproot blackberry canes and attached roots. This is most effective when soils are moist, loose and free of rocks. Follow-up is needed to treat resprouts from the broken roots. Mowing or cutting followed by tilling, then raking to remove root fragments is somewhat effective, but causes high levels of soil disturbance and requires follow-up resprout control. Repeated mowing, or cuttings until root reserves are depleted may also be effective but causes high levels of disturbance.

Grazing: Goats may be effective in controlling new growth. Literature suggests that this does not control older canes, but the East Bay Municipal Water District has used goats to clear blackberry in the Mokelumne River watershed and report that old canes are killed by girdling. It requires repeated follow-up treatments to control resprouts.

Prescribed Burning: Prescribed burning may be used to initially remove biomass, but is ineffective in itself to treatment Himalaya blackberry on its own.

Biological Control: There are no approved biological controls for Himalaya blackberry due to its close relation to the agricultural blackberry.

Chemical Treatment: As discussed above, applications of triclopyr and glyphosate are effective for controlling Himalaya blackberry in combination with other methods.

MONTEREY PINE (*Pinus radiata*)

Growth Characteristics

Monterey pine is coniferous evergreen tree up to 110 feet in height with trunks up to 6 feet in diameter. Although young trees are typical of most pines in their conical shapes, mature trees often develop flat, umbrella-like canopies. They are the most rapidly growing of all pine species.

Reproduction Characteristics

Monterey pines reproduce by seed encased in cones that remain closed and sealed until their second year or longer. The cones are serotinous and do not release seeds unless subject to high temperatures during very hot days or fires. Because of the mild climate in coastal California, therefore, Monterey pine reproduction is highly fire-dependent. Monterey pine is not capable of resprouting.

Hand Labor Treatment: Seedlings come out easily when pulled by hand. Roots of saplings can be dug up using a Pulaski tool or mattock. This method is very strenuous and creates high levels of soil disturbance.

Mechanical Treatment: Mature trees may be felled with chainsaws.

Grazing: Grazing is ineffective in controlling Monterey pine.

Prescribed Burning: Prescribed burning may be used to kill seedlings or saplings, but is not practical for mature trees due to high fuel loads and risk of escape.

Biological Control: There are no approved biological controls for Monterey pine.

Chemical Treatment: Chemical treatments with Roundup® are effective in controlling Monterey Pine seedlings.

HERBACEOUS INVASIVE PLANTS

ARTICHOKE THISTLE (*Cynara cardunculus)*

Growth Characteristics

Artichoke thistle (*Cynara cardunculus*), also know as cardoon, is a large spiny perennial herb up to seven feet tall. It looks similar to the commercially available artichoke except that the phyllary bases and receptacles (the edible portions) are only about half the size. Flowers that appear from April through July are a deep blue-purple color. Dense colonies grow as monocultures, displacing natural vegetation, wildlife, and livestock.

Reproductive Characteristics

Artichoke thistle reproduces only by seed. Most seeds fall near the parent plant but can disperse up to 65 feet by wind. Most seeds germinate in the fall with the first rains, but some can germinate all year. Seeds are moderately long lived, up to 5 years after dispersal.

Control Strategy/Prescriptions

Hand Labor Treatment: The large size and spiny nature of artichoke thistle makes hand pulling or digging challenging. Grubbing out roots is possible for areas with low densities but not practical for large infestations. New shoots will sprout back from remnants of the tap root (which can extend up to eight feet deep) so repeated treatment is necessary.

Mechanical: Large scale mechanical treatment requires repeated plowing or cultivation and is not recommended on wildlands due to the high levels of soil disturbance.

Biological Control: No biological control agents have been approved or released for artichoke thistle due to its close relationship with the crop species. However, the artichoke fly (*Terrelia fusicornis*) has been observed on artichoke thistle throughout California. The fly feeds on the flowers and seedheads, but the full impact of the fly on artichoke thistle is unclear.

Prescribed Burning: There is little information on the effectiveness of this technique on artichoke thistle. Fire may help defoliate the plants and kill some seeds, but artichoke thistle is known to be one of the first colonizers after a fire.

Chemical Treatment: Application of glyphosate has been shown to be highly effective for artichoke thistle control if applied on the cut stumps. The top of the plants should be removed as close to the ground as possible from February through May and a 25% glyphosate solution applied immediately to the stump. Glyphosate may also be effective applied as a 2% solution to mature bolting plants . It can also be controlled by spraying with the selective herbicide Garlon 3A® in March. The Contra Costa Department of Agriculture has shown recent success by spraying from February through May with a combination of the broadleaf selective herbicides dicamba and Milestone®, the latter of which has both contact and pre-emergent capabilities.

BULL THISTLE (*Cirsium vulgare*)

Growth Characteristics

The biennial bull thistle (*Cirsium vulgare*) grows over the summer months in the first year as a basal rosette with stiff hairy foliage and simple alternative leaves. The leaves are unlobed or pinnately lobed. The tip of the leaf is pointed and the margins are toothed with spines. The root is a fleshy taproot the first year, with fibrous root systems developing the second year. The roots grow up to two feet deep. The thistle stems elongate to form flower stalks the second year. The elongated stems have alternating leaves. Dark pink to purple flowers with spined bracts develop from June through October.

Reproductive Characteristics

Bull thistle reproduces by seed only; it has no means of vegetative reproduction. The seeds germinate in the fall after the first rains. Germination occurs under a wide temperature range and can occur under low moisture conditions. The seeds are short-lived; most seeds either germinate in the first year or die, but seeds buried deeper than about six inches can live up to three years.

Control Strategies/Prescriptions

With the right combination of control measures, it should be possible to eliminate bull thistle from selected areas due to its inability to reproduce vegetatively and short seed life.

Hand Labor Treatment: Hand pulling and cultivation can be effective in controlling bull thistle. Plants should be pulled or cut well before seed set. Plants cut close to flowering time can produce seed on the cut portion, so flower heads should be bagged to prevent spread.

Mechanical Treatment: Mowing or slashing can be effective if plants are cut before seed is set. Mowing before seed production may eventually eliminate this thistle, but only if repeated until the seedbank is depleted (1-3 years).

Grazing: No information is available regarding grazing as a potential treatment method for bull thistle.

Prescribed Burning: No information is available regarding prescribed burning as a potential treatment method for bull thistle.

Biological Control: The bull thistle seedhead gall (*Urophora stylata*) is a host-specific biological control agent that has been released in California from Europe. It was released at ten sites in El Dorado, Marin, Mendocino, Modoc, San Luis Obispo, Shasta, and Tulare Counties by the USDA-ARS. Post-release surveys have failed to find any established populations, however galls with larvae have been found and three sites have shown recovery of populations. If determined to be a feasible option, EBRPD should follow-up with USDA-ARS to see if there is any possibility of releases in the East Bay Hills.

Chemical Treatment: Herbicides can be used to control bull thistle. Based on test results on related thistle species, glyphosate, clopyralid, and dicamba would be most effective if used prior to seed set.

CAPE IVY (*Delairia odorata)*

Growth Characteristics

Cape ivy (*Delairia odorata*), also known as German ivy, is a perennial vine with shiny, five- to six-pointed leaves, one on each node, usually with two small stipule-like lobes. Foliage is green to yellow-green and has a distinct odor. Plants have extensive waxy stolons running above and below ground. Below-ground stems are purple. Each flower is a yellow, round discoid head the size of a dime. Flowers are arranged in groups of twenty or more.

The period of most rapid vegetative growth is February to June, with some dieback occurring during July to October in areas without a constant water source. After flowering and a month or two of rapid vegetative growth, this vine starts storing sugars from photosynthesis as starch in underground storage organs. It flowers December to February.

Reproductive Characteristics

Cape ivy apparently reproduces only vegetatively in California. It spreads vegetatively by stolons and fragmentation of stolons. Ninety-five percent of fragments of green stolons containing only one node establish, and drying stolon fragments in full sun for ten weeks does not stop them from rooting.

In Australia and in its native South Africa it reproduces by seed as well, which results from homogamous, radiate, self-incompatible flowers. Cape ivy flowers extensively in California, but evidently forms non-viable seeds. It is possible the naturalized cape ivy in California is derived from a single genetic stock and, since this species is self-incompatible, California populations do not produce viable seed.

Control Strategies/Prescriptions

Cape ivy is difficult to eliminate for two primary reasons: stolons and underground parts readily fragment while being removed, and plants will grow from almost any remaining fragment. The most effective control technique depends on the site topography, proximity of water, type of non-target vegetation on the site, age and size of the infestation, importance of impacts to non-target species, and type and quantity of resources available for control efforts. All methods require appropriate timing and supplemental revegetation by desirable species.

It is necessary to monitor removal sites every two months the first year and every four months the second year to locate and kill resprouts. Location and retreatment of resprouts is imperative or in six to eight months the ivy can re-infest the whole area from which it was removed. After the second year the site should be examined yearly to check for newly establishing populations. This is particularly important if a stream is present or if seasonal flooding occurs. Immediate removal of small new populations can save many hours of removal efforts a few months later and prevents further spread to other sites by fragmentation.

Hand Labor Treatment: Hand labor treatment typically requires clearing away native and invasive plant material to gain visual and physical access to locations with cape ivy stems emerging from the ground. Roots and stems must be teased out of the ground using a pointed or three-pronged mini-rake to loosen the soil. At some sites, where cape ivy is growing mat-like on the ground, it has been possible to roll up the entire infestation like a carpet using a potato hoe or rake. Removed cape ivy

should be placed in or on plastic and, if feasible, removed from the area. Putting soda lime into cape ivy container bags will hasten the otherwise slow breakdown of this plant material. Hand labor treatment is sometimes followed with spot chemical treatment of resprouts. Cape ivy tissues should not be put through a chipper or sent unbagged to a dump site. Both would likely result in the spread of cape ivy in disposal areas.

Returning at four- to eight-week intervals is necessary to locate and remove overlooked and resprouting plants. Hand labor treatments are resource-intensive but can be accomplished where chemical applications cannot be used. The amount of disturbance to non-target species varies with the type of vegetative community infested, but it can result in increased erosion or in colonization by other invasive plants. Supplemental revegetation needs should be considered on a site-by-site basis.

Mechanical Treatment: Mechanical treatments are not effective because complete removal of the root system is necessary.

Grazing: Cape ivy contains pyrrolizidine alkaloids and xanthones that make it unsuitable forage for most fauna. Pyrrolizidine alkaloids such as retronecine, found in cape ivy foliage and flowers, are known to be toxic to mammals and to spiders.

Prescribed Burning: Prescribed burning has not yet been attempted on cape ivy because of the high moisture content of its foliage.

Biological Control: An initial assessment of potential biological control agents for cape ivy conducted in South Africa suggests that there are seven promising insect candidates, including moth and beetle larvae and root-, stem-, and seed-feeding insects. Led by Cal IPC, an effort is underway to raise funds to continue to support the efforts of the USDA Albany lab in developing biological control agents for cape ivy. Some of the more promising insects are being tested in South Africa. Call USDA's Western Regional Research Center for the latest information concerning biological control research for Cape Ivy.

Chemical Treatment: A mixture of foliar-sprayed 0.5 percent glyphosate (as Roundup®) + 0.5 percent triclopyr (as Garlon 4®) + 0.1 percent silicone surfactant (as Silwit®) in water, applied as a foliar spray at 6.4 liters/hectare proved effective in killing even long-established and extensive infestations of cape ivy. Applications must be done in late spring when the plant is photosynthesizing actively but is past flowering, so the active ingredients move down with the sugars that are transported to underground storage organs. This mixture has a low concentration of active ingredients, which results in a slow, progressively deadly impact on dense cape ivy infestations with no measurable damage to non-target species. Since the mixture contains a surfactant and triclopyr, it should be used cautiously and only within the guidelines specified on the label, especially where the water table is only a few inches below the surface or along pond or stream banks.

HARDING GRASS (*Phalaris aquatica)*

Growth Characteristics

Harding grass (*Phalaris aquatica*) is a perennial grass that forms large clumps with short rhizomes that grow out from the base. It was introduced from the Mediterranean region as a livestock forage plant.

Reproduction Characteristics

Harding grass reseeds fairly effectively, but seed spread is not uniform. Uninfested areas adjacent to Harding grass populations should be monitored to detect if it is spreading from seed.

Control Strategy/Prescriptions

Hand Labor Treatment: Hand pulling is not effective in controlling Harding grass because of its large size and root depth.

Mechanical Treatment: Repeated clipping or mowing during the active growth period seems to be able to control Harding grass. Several repeated defoliations over a single growing season may be most effective.

Grazing: Harding grass is very tolerant of heavy grazing, and the frequency and intensity of grazing required to control Harding grass would damage desirable resources, so this does not appear to be an suitable strategy.

Biological Control: Biological controls are not a feasible strategy due to the forage value of Harding grass and relatives for livestock.

Prescribed Burning: Prescribed burning during the winter can reduce subsequent growth for about two years allowing competitive desirable fire-tolerant species to become established. Because Harding grass requires two years to recover, a two-year burning regime could be most effective in controlling it.

Chemical Treatment: Relatively high rates of dicamba (Banvel®) applications have been effective in controlling Harding grass. The most effective strategy appears to be repeated mowing followed by applications of glyphosate (Round-Up®) to the regrowth.

ITALIAN THISTLE (*Carduus pycnocephalus*)

Growth Characteristics

The annual Italian thistle (*Carduus pycnocephalus*) varies in height from ankle- to head-high. Its leaves are white-woolly below, hairless-green above and deeply cut into two to five pairs of spiny lobes. The terminal lobe spine grows longer and more rigid than the other spines; stems are slightly winged. Flower heads are covered with densely matted, cobweb-like hairs. The thimble-sized, rose to pink to purple flowers are clustered in groups of two to five. Flower heads are smaller and fewer than those of bull thistle or Canada thistle, and Italian thistle has narrow bracts under its heads with many tiny, firm, forward-pointing hairs.

Reproductive Characteristics

Italian thistle reproduces by seed only; it has no means of vegetative reproduction. An annual or biennial, it flowers from May through July and plants typically die early the following summer. A single plant can produce 20,000 seeds in one season. Seeds are produced in two forms: brown seeds and silver seeds. Brown seeds generally remain in the flower heads, falling with them to the ground at

the end of the season. These seeds can germinate at lower temperatures than the silver seeds. Silver seeds are dispersed by wind and can remain dormant in the soil longer than brown seeds, up to 8 to 10 years.

Germination generally occurs in autumn with the first substantial rains. In New Zealand, in a few areas with cold winter temperatures, this species was found to germinate as late as June. Seeds can germinate from depths of three inches (8 cm) but usually germinate at less than one inch (0.5 cm). Partly because of its germination requirements and timing, Italian thistle has been rapidly spreading on rangelands previously dominated by non-native annual grasses. It germinates under temperature and moisture regimes and in seedbed environments that otherwise inhibit germination of the non-native annual grass species that currently dominate California grasslands.

Drought favors an increase in Italian thistle. Any disturbance of vegetative cover encourages establishment of this thistle. Seedlings establish best on bare, disturbed soil; in areas with dense groundcover they cannot establish. Plants overwinter as rosettes and produce flowering stalks in late spring before the onset of summer drought. The rosettes can be so dense that they blanket the soil, inhibiting germination of all other plants.

Control Strategies/Prescriptions

With the right combination of control measures, elimination of Italian thistle from selected areas should be possible. Italian thistle's inability to reproduce vegetatively makes control easier, but constant monitoring will be necessary due to its potentially long seed dormancy (up to 10 years).

Hand Labor Treatment: Hand pulling is used at Golden Gate National Recreation Area for small patches, but the root must be severed at least four inches (10 cm) below ground level so the plant does not regrow. Plants should be pulled well before seed set. Plants which are cut close to flowering time can still produce seeds on the cut portion.

Mechanical Treatment: Mowing or slashing is not reliable because plants can regrow and still produce seeds. A significant amount of seed can be produced even if thistles are consistently mowed at three inches (8 cm). Cultivation before seed production may eventually eliminate this thistle, but only if repeated until the seedbank is depleted (up to 10 years).

Grazing: Grazing management showed promising results in controlling Italian thistle populations in Australia. Sheep or goats must be used; cattle find this plant unpalatable. Livestock are removed from infested areas when thistles start to germinate in autumn and not grazed until plants reach a height of four to six inches (10-15 cm). Areas are then heavily grazed at twice the normal stocking rate for three weeks. For this method to be successful, the autumn grazing break is necessary so that vigorous growth of other plants is allowed to occur, forcing the thistles to grow tall and more tender. Continuous grazing significantly reduces thistle numbers but is not as effective as the use of an autumn break. Recent research suggests that cattle can be trained to select Italian thistle for grazing as a means for control. This research should be tracked and tested for control of Italian thistle and other similar herbaceous weeds.

For larger areas where thistles are dominant, cultivation and cropping is a successful method of control provided a vigorous perennial pasture is established immediately after the cropping phase. In high fertility situations, using a roller to compact the soil is recommended during seedbed preparation

but not during seed sowing. This action typically forces a massive germination of thistles that can be destroyed during cultivation.

Prescribed Burning: No information is available regarding prescribed burning as a potential treatment method for Italian thistle.

Biological Control: Biological control methods offer limited options for containment of Italian thistle. The subject has been extensively researched, but there are no USDA-approved biological control agents recommended for use in California. Many insects feed on Italian thistle, but the few that effectively control infestations also feed on economically valuable species. Only three insect species, *Psylloidas chalcomera*, *Rhinocellus conious*, and *Ceutorhynchuys trimaculatus*, tested host-specific and caused injury sufficient to decrease reproductive potential of Italian thistle. Concern that these insects may prey on several of California's endangered native thistles in the genus *Cirsium* has limited the use of these insects for control of Italian thistle.

Several species of rust fungi infest Italian thistle. *Puccinnia cardui-pycnocephali* is apparently restricted to Italian thistle, although *P. cauduorum, P. centaureae*, and *P. galatica* also are found on the plant. Rust fungus reduces growth, especially during the rosette and vegetative phase, but it has insignificant effects on flower or fruit production. Optimal conditions for rust infection and decline of host plants are 65 to 70 degrees (18 to 20 degrees Celsius) and 90 to 100 percent humidity.

Chemical Treatment: The use of selective broadleaf herbicides has been shown to be effective in controlling Italian thistle.

MILK THISTLE (*Silybum marianum)*

Growth Characteristics

The annual or biennial milk thistle (*Silybum marianum*) is a robust plant with large spiny leaves and milk coloted curvilinear blotchs and purple flowers. Plants grow as flat rosettes in the late autumnt early winter and grow rapidly into large cabbage-like plants in the spring prior to flowering.

Reproductive Characteristics

Flowering begins in late spring and continues into early summer. Milk thistle reproduces by seed only; it has no means of vegetative reproduction. The seeds germinate in the fall after the first rains. The seeds are long-lived and can remain viable in the soil for up to 9 years.

Control Strategies/Prescriptions

With the right combination of control measures, milk thistle may be controlled, but only if combined with seeding of native or desirable naturalized grasses and forbs.

Hand Labor Treatment: Hand pulling has limited success. Digging milk thistle plants out by hand can create disturbance conditions well-suited to promote thistle germination.

Mechanical Treatment: Mowing can be effective if plants are cut before flowers are fully developed. If not, the cut flowers should be bagged because seed may still develop in the cut flower heads.

Mowing should begin in May and be repeated for four to six times during the spring and summer to prevent seed maturation. Two or more years may be required to show results.

Grazing: Livestock will graze milk thistle but not until after it has flowered and set seed, so this is not a viable treatment.

Prescribed Burning: No information is available regarding prescribed burning as a potential treatment method for milk thistle.

Biological Control: The European weevil *Rhinocyllus conicus* was released in southern California in 1971 for milk thistle control. This weevil has an annual life cycle, and attacks thistles in the genera Carduus, Onopordum, Silybum and Cirsium. The larvae of *R. conicus* do not always attack the seed tissue of milk thistle, even though they are often found in the seed head.

Chemical Treatment: Herbicides can be used to control milk thistle most effectively in the seedling and rosette growth stages. The more mature the plant, the more resistant it is to control with herbicides. Experiments with approved herbicides such as glypohosphate (Round-Up®) or dicamba should be implemented and results documented to determine effective strategies.

OBLONG SPURGE (*Euphorbia oblongata)*

Growth Characteristics

Oblong spurge (*Euphorbia oblongata*) is a perennial with stems somewhat woody at the base with erect stems bearing linear to slightly oval leaves. It has a woody taproot that branches near ground level. The base of the stems support crown buds that can produce new sprouts and roots. It can grow in dense patches displacing native vegetation and wildlife.

Reproduction Characteristics

Oblong spurge produces clusters of yellow flowers in spring and summer. Otherwise the reproductive biology of this species is not well documented.

Control Strategy/Prescriptions

There is little documentation of effective control for oblong spurge.

Hand Labor Treatment: Hand pulling is effective in controlling small infestations of this weed but is very difficult because of deep roots. Gloves, goggles, and other protective clothing should be worn because the milky sap of spurge can irritate the skin and eyes. Cutting or pulling in the spring or summer before seeds are set will help deplete the seed bank and lessen re-infestation.

Mechanical Treatment: Based on results with other spurge species, mowing is not effective in reducing infestations but may help reduce seed production if repeated at 2-4 week intervals.

Grazing: There is no documentation of the effects of grazing on oblong spurge. Another spurge species is known to be toxic to cattle and horses, but not to goats or sheep, and grazing effects are currently being researched.

Biological Control: There are not current biological control programs for oblong spurge. There are several insects approved for biological control of other spurge species in the United States, but none in California.

Prescribed Burning: Prescribed burning has not been successful in controlling other spurge species because of rapid regeneration. There is no documentation concerning its effects on oblong spurge.

Chemical Treatment: There is no documentation of the effectiveness of herbicide in controlling oblong spurge, but other spurge species are very resilient to chemical control due to regeneration from dormant root buds and a large pool of carbohydrate reserves.

PAMPAS GRASS AND JUBATA GRASS (*Cortaderia selloana, C. Jubata)*

Growth Characteristics

Pampas grass (*Cortaderia selloana*) and jubata grass (C. jubata) are perennial grasses 6 to 13 feet tall with long leaves folded at the midrib and arising from a tufted base or tussock. The inflorescence or flower cluster is a plumed panicle at the end of a stiff stem. Stems are equal to or slightly longer than the tussock. Plumes nearly always consist of light violet to silver-white hairy female flowers that rarely produce seed.

Pampas grass is easily confused with jubata grass. As shown in Table G.5, the two species are distinguished by stem height, leaf, plume, and spikelet color, florets, leaf tip, and presence of viable seed. The tussocks of jubata grass are less erect and more spreading and not fountain-like, when compared to tussocks of pampas grass.

Table G.5 Differing Characteristics Between Pampas and Jubata Grasses

Characteristic	Pampas Grass *Cortaderia selloana*	Jubata Grass *Cortaderia jubata*
Stem (culm) height	equal to or slightly longer than tussock in female plants; two times longer in male plants	2-2.5 times longer than tussock
Leaf color	glaucous-green	bright to deep green
Plume color	light violet to silvery white; female plants with lighter plumes than males	pinkish to deep violet
Spikelet color	glumes white; males sometimes purplish near base	glumes purple
Florets	males sparsely or not at all hairy; females densely hairy at base, awns twice the length of hairs	hairy at base; awn slightly extending beyond hairs
Leaf tip	bristly and curled	not bristly or curled
Viable seed	only when male and female plants are present	yes

Source: LSA Associates Inc., 2008.

Reproductive Characteristics

Pampas grass and jubata grass are typically propagated for ornamental purposes through division of mature plants. In nature they produce flowers two to three years after germination. Flowering usually occurs from late August though September, but occasionally in winter. These species are considered gynodioecious, that is, flowers of some plants consist of both male and female parts on the same flower, but only the male parts are functional. Some plants bear only female flowers. Thus, these species are functionally dioecious. Over the years, selection for ornamental plants in California has

been for the showier plumes of the female plants. Consequently, few opportunities exist for seed production. This may account for the lack of spread of this species in California in past years.

Populations that escaped from cultivation probably occurred in areas where seeds were produced. This can occur when both male and female plants are present in a population or when an occasional perfect flower (with both male and female parts) is produced on a typically male plant. Little is known of the germination of *Cortaderia* from seed. Vegetative reproduction can occur when fragmented tillers receive adequate moisture and develop adventitious roots at the base of the shoot.

Establishment of seedlings generally occurs in spring and requires sandy soils, ample moisture, and light. Seedling survival is low in shaded areas or in competition with grasses or sedges. Since few seeds are produced in California, little is known of the growth requirements. Unlike *Cortaderia jubata, C. selloana* can tolerate winter frost (Costas-Lippman 1977); it also tolerates warmer summer temperatures, more intense sunlight, and moderate drought. This accounts for its success as an ornamental in the Central Valley of California and its establishment as a weed along the American River near Sacramento. Once established, roots of a single plant can occupy a soil volume of about 1,100 square feet (103 m2). Lateral roots can spread to 13 feet (4 m) in diameter and 11.5 feet (3.5 m) in depth. Plants are capable of surviving about 15 years.

Control Strategies/Prescriptions

Control of pampas grass and jubata grass are similar, but few strategies are available. Burning does not provide long-term control, as plants resprout shortly thereafter. Infestations sometimes can be averted by overseeding open disturbed sites with desirable vegetation to prevent establishment of seedlings.

Hand Labor Treatment: Hand pulling pampas or jubata grass seedlings is highly effective. For larger plants however, a Pulaski tool, mattock, or shovel are the safest and most effective tools for removing established clumps. To prevent resprouting, it is important to remove the entire crown and top section of the roots. Detached plants left lying on the soil surface may take root and reestablish under moist soil conditions. A large chainsaw or weedeater can expose the base of the plant, allow better access for removal of the crown, and make disposal of the detached plant more manageable. Cutting and removing or burning the inflorescence prior to seed maturation in late summer may be important if seed production occurs in escaped populations of pampas grass.

Mechanical Treatment: No effective mechanical treatments have been documented to treat pampas grass.

Grazing: The success of grazing has not been reported in the United States, but cattle have been shown to provide effective control for pampas grass in commercial forests of New Zealand.

Prescribed Burning: Burning does not provide long-term control. The growing points of the grass are protected by surrounding leaves, which leads to rapid resprouting following a burn.

Biological Control: No insect or fungal control efforts have been investigated for any species of *Cortaderia*.

Chemical Treatment: Control of pampas and jubata grass can be achieved by spot treatment with an application of glyphosate at about 2 percent solution or eight qts/100 gal. The addition of a non-ionic or silicone-based surfactant may enhance foliar penetration of the herbicide. For most effective control, plants should be sprayed to wet, but not to the point of herbicide runoff. In one study, over 90 percent control was obtained during the first season, but continued spot applications were necessary to prevent rapid reestablishment.

Fall applications result in better control compared to summer applications because photosynthetic assimilates are translocating downward at a faster rate late in the season. However, if viable seeds are produced, it may be necessary to apply the herbicide prior to seed maturation. Although studies were conducted on jubata grass, it is likely that low-volume (20 gal/ac) treatment with glyphosate at 4 percent can also provide excellent control of pampas grass. The reduced volume can lower the amount of herbicide used as well as the cost of the treatment. Rope wick applications of glyphosate have also proven effective, but good coverage is essential or tillers will recover. For large clumps, the top foliage can be removed by cutting or burning and the regrowth treated with a systemic post-emergence herbicide. This method reduces the amount of herbicide applied compared to herbicide treatment alone.

POISON HEMLOCK (*Conium maculatum*)

Growth Characteristics

Poison hemlock (*Conium maculatum*) is a member of the carrot family. It is usually a biennial, with first-year plants producing ground-level rosettes. During the second year plants grow from two to ten feet tall with a stem that is ribbed, hollow, and has purplish streaks or splotches. Small, white flowers grow in many umbrella-shaped clusters, each supported by a stalk. Leaves have a somewhat fern-like appearance and are finely pinnately divided. When crushed, they have a rank odor.

Reproductive Characteristics

Poison hemlock reproduces only by seed, which is dispersed by water, mud, wind, animal fur, human clothing, boots, and machinery. It has no means of vegetative reproduction.

Reproductive plant parts develop in mid-April, usually one year after germination. In summer, once plants have set seed, they dry up and die leaving tall stalks to shade out other plants. The seed of poison hemlock is fully developed by mid-June. Plants disperse about 90 percent of their seed in September through December, with the remainder dispersed by late February. This lengthy dispersal period allows poison hemlock to produce new seedlings continuously for several months.

Poison hemlock has a large range of conditions in which it can germinate. It can germinate at temperatures greater than 48 degrees (9.4 degrees Celsius) and lower than 93 degrees (33.8 degrees Celsius). It can germinate in darkness as well as in light. About 85 percent of seed produced is able to germinate as soon as it leaves the parent plant. The remainder is dormant and requires certain environmental conditions (thought to be summer drying) in order to germinate. This ensures that some seed will remain in the seed bank until the following growing season. Seed can remain viable in the soil for up to three years. It germinates most readily in soil, but can also germinate in sand. The combination of long seed dispersal period, seed dormancy, and non-specific germination requirements enable poison hemlock seedlings to emerge in almost every month of the year.

Germination takes place in all months of the year except April, May, and July, with late winter and early spring being the periods of greatest germination. Most vegetative growth occurs in winter months, with plants developing a deep taproot that is sometimes branched.

Control Strategies/Prescriptions

Mechanical or chemical removal of poison hemlock is relatively easy, but complete eradication may be difficult due to reintroductions and the presence of viable seeds in the soil. Poison hemlock requires active control measures or it can become dominant on a site, particularly disturbed areas such as roadsides.

Hand Labor Treatment: Hand pulling of poison hemlock is effective, especially prior to seed set, and easiest when the soil is wet. Because of the biennial nature of the plant, the entire root system does not need to be removed Follow-up cultivation is necessary to deal with any seedlings and if possible vigorous desirable vegetation should be established to compete with any further seedling growth. Poison hemlock remains toxic for several years after being pulled, and it is wise not to leave the dead plants where they might be eaten by wildlife or children.

Mechanical Treatment: Spring mowing has proven effective in killing mature plants, yet regrowth may occur and new seedlings may continue to establish. A second mowing in late summer is recommended to eliminate remaining or subsequent growth. Because poison hemlock seed has been shown to germinate up to three years after dispersal, a third year of mowing may be necessary.

Grazing: Poison hemlock is toxic to livestock, wildlife, and humans. Cattle, sheep, horses, pigs, goats, and fowl are all susceptible to its toxicity. Poisoning occurs in horses when they eat a quantity approximately equal to 0.25 percent body weight and in cows, 0.5 percent body weight. Poisonings are usually not caused by direct foraging of poison hemlock, but by consumption when it is mixed in stock feed. Wildlife is also susceptible to the toxic effects of poison hemlock. Ten percent of an elk population on Grizzly Island, California, died from ingesting poison hemlock in 1985.

Prescribed Burning: Burning is likely not an optimum control option. In areas where poison hemlock is the dominant vegetation (typically moist environments), sufficient dried material would not be available to provide adequate fuel to control poison hemlock before fruit maturation. This method has yet to be tried on poison hemlock.

Biological Control: Although biological control is being examined, at this time there is no USDA approved biological control agent for use on poison hemlock in California.

Chemical Treatment: Glyphosate at a rate of 1.0 lb/acre plus surfactant has proved effective in killing poison hemlock, especially in the rosette stage.

PURPLE STARTHISTLE *(Centaurea calcitrapa)*

Growth Characteristics

Purple starthistle (*Centaurea calcitrapa*) is a biannual thistle with a mounding growth habit and heads of purple flowers surrounded by long, stout, sharp-pointed spines. Plants form rosettes in their first growing season with deeply pinnately-lobed, gray-hairy leaves with light-colored midribs; older rosettes have a circle of spines in the center. Mature plants are one to four feet high, densely and rigidly branched, and have numerous flower heads.

Reproductive Characteristics

Purple starthistle reproduces only by seed. It is a rosette-forming herb. Most plants remain in the rosette stage for one year, bolt, flower, and set seed in the second growing season, and then die. Some individuals may complete their lifecycles in one year in extremely favorable circumstances (annual) or only after several years in unfavorable circumstances (monocarpic perennial). The seeds have no pappus, and most are deposited below or near the parent plant. Viable seeds can be found in the heads of senesced plants, which may break and be blown long distances, scattering seeds as they go. Purple starthistle seeds can remain dormant in the soil for many years. Longevity of seed in the soil is unknown.

Control Strategies/Prescriptions

No single control method, or any one-year treatment plan, will achieve effective control of an area contaminated with purple starthistle. The fast growth, deep root system, fast rate of spread, and high seed viability of this plant require long-term cooperative integrated management. Control measures can be complicated by the lark sparrow, which selectively nests in purple starthistle infestations.

Hand Labor Treatment: Grubbing or digging can control small infestations. Plants should be cut at least two inches below the soil surface early in the growing season. They are easiest to see after they have begun to bolt, but they should be cut before they begin to flower in order to prevent the release of viable seed. If plants are cut after they have begun to flower, they should be removed from the site and destroyed. Follow-up treatments will be necessary as field tests indicated that 10-15 percent of plants cut below the root crown re-sprouted.

The tough roots of purple starthistle can be severed by a Pulaski tool. To kill purple starthistle and prevent resprouting, chop the root deep enough so that the root crown is cut out and no purple color in the stem can be seen, at least 3 inches below the base of the plant. In riparian areas, remove purple starthistle manually as moist soils will facilitate pulling.

Purple starthistle can be removed during any stage of the plant's life cycle. It is more effective to concentrate efforts on older, larger, and more conspicuous plants rather than rosettes that are difficult to find. Remove plants before seeds are formed to prevent the spread of new seeds. Continual monitoring will catch rosettes when they bolt. Monitor and eradicate small, new infestations of purple starthistle. Check soil sources for weed seeds before introducing the soil to new areas, such as highway median strips or other types of roadways. Thoroughly clean vehicles after their use on land infested with purple starthistle.

Mechanical Treatment: Mowing is not an effective method of control. The rosettes are too low to be cut and plants that have already bolted often respond to mowing by producing multiple rosettes. Mowing plants that have begun to flower will spread the cut flower heads, which may still be capable of dropping mature seed. Mowing can cause resprouting populations to explode.

Grazing: Purple starthistle's stiff, sharp spines and bitter taste discourage feeding by cattle, deer, and rodents. It replaces palatable species in some grazed areas, and dense stands of mature plants can make areas inaccessible to livestock and humans. Its spines are thicker and stronger than those of yellow starthistle and do not fall from the plants in autumn as do those of yellow starthistle. Because

of this, forage that may grow in infested areas during fall and winter after purple starthistle has senesced may be inaccessible to grazers.

Conventional grazing by sheep or cattle will not control purple starthistle and in fact can promote it, because grazing animals usually avoid this plant and selectively feed on species that would otherwise compete with it.

Prescribed Burning: No information is available regarding prescribed burning as a potential treatment method for purple starthistle.

Biological Control: There are no locally-accepted biological control measures for purple starthistle.

Chemical Treatment: Application of glyphosate in the late spring-early summer on the rosettes and early blooming plants after adjacent desirable annual species have set seed is an effective control. Care must be taken to limit this treatment to areas devoid of native perennials because this herbicide is non-selective. Selective herbicides that are effective in these cases include clopyralid (Transline®), dicamba (Banvel®); and Garlon 3A®. Herbicides should be applied on a site-specific basis to minimize impacts as they can affect desirable non-target broadleaved plants.

YELLOW STARTHISTLE (*Centaurea solstitialis*)

Growth Characteristics

In California, yellow starthistle (*Centaurea solstitialis*) grows as a deep-taprooted winter annual, or rarely as a short-lived perennial. It produces one to many solitary, spiny, yellow flower heads during late spring, summer, and fall. Seeds begin to germinate soon after fall rains, and young plants grow as prostrate to ascending taprooted rosettes until bolting occurs in late spring or early summer. Stem leaves of bolted plants extend downward, giving the stems a winged appearance. Flowering plants range from ankle to shoulder height and change color from green to bluish-green in summer. Flower heads are generally produced from June through September. The heads are initially produced on branch tips, but robust plants may produce heads in the branch axils later in the season. The main phyllaries (flower head bracts) are palmately spined with a single stout, apical spine and a few much smaller, lateral spines. Some individuals produce shorter apical spines. The heads contain two types of fruits or achenes. Most are cream to tan with a white pappus or plume; achenes in the outer ring are darker and lack a pappus.

Reproductive Characteristics

Plants reproduce only by seed and generally flower from May to September. When adequate moisture is available, yellow starthistle can survive as a short-lived perennial and flower throughout fall, winter, and spring. However, the flowers produced during winter are often killed by frost. Almost all plants are self-incompatible and require pollen from a genetically compatible plant to produce seed.

European honeybees are an important pollinator, and in some populations are responsible for 57 percent of seed set. Seeds produced per head (30-80) and flower head production per plant (1-1,000) are variable, depending on soil moisture levels and intensity of competition. Large plants can produce nearly 75,000 seeds. Seed production in heavily-infested areas varies between 50 to 200 million seeds

per acre. Studies of seed survival in soil have found significant survival to ten years. Seeds typically germinate in late fall or early winter, when soil moisture is present and overwinter as basal rosettes.

Germination responses in yellow starthistle are greatly reduced in dark environments and by exposure to light enriched in the far-red portion of the spectrum. The two types of achenes also differ in response to light. During early seedling establishment, root growth is vigorous and can extend deeper than one meter (3.3 ft), providing plants with access to deep soil moisture reserves during dry summer months. Reduced light levels cause the rosettes to produce fewer but larger leaves and to assume a more upright growth form. Reduced light levels also significantly reduce root growth and flower production. Consequently, survival and reproduction are significantly reduced in shaded areas and the plant is probably less competitive in dense stands of established perennials. Bolting occurs from late spring to early summer, and spiny flower heads generally are produced from early summer to late summer or fall. The spines on the flower heads may protect them from herbivory by large animals, but they do not prevent significant herbivory by grasshoppers or seed predation by birds.

Control Strategies/Prescriptions

Integrated pest management systems are most effective where yellow starthistle is concerned, particularly systems that incorporate containment, reduction, and eradication. Eradication may not be practical except in previously un-infested areas. An effective eradication program is closely tied to prevention; eradication is not complete until all viable seeds are depleted from the soil.

It is important to prevent large-scale infestations by controlling new invasions. Spot eradication is the least expensive and most effective method of preventing establishment of yellow starthistle. In established stands, any successful control strategy will require dramatic reduction or, preferably, elimination of new seed production, multiple years of management, and follow-up treatment or restoration to prevent rapid re-establishment.

Effective control using any of the available techniques depends on proper timing. Combinations of techniques may prove more effective than any single technique. For example, prescribed burning followed by spot application of post-emergence herbicides to surviving plants can prevent the rapid re-infestation of the treated area. Similarly, combining mowing and grazing, revegetation and mowing, or herbicides and biological controls may provide better control than any of these strategies used alone. Effective combinations may depend on location or on the objectives and restrictions imposed on land managers.

Hand Labor Treatment: Manual removal of yellow starthistle is most effective for controlling small patches or where plants are sparsely located in a grassland system. It can also be important in steep or uneven terrain where mechanical tools are impractical or impossible to use. To ensure that the plants do not recover, all aboveground stem material must be detached; leaving more than two inches of rooted stem can result in recovery if leaves and buds are still attached to the base of the plant. Optimal timing for manual removal is after plants have bolted but before they produce viable seed. At this time, plants are easy to recognize and some or most of the lower leaves have senesced. Hand removal should be considered in areas with competing vegetation, as the starthistle will develop a more erect, slender stem with few basal leaves. These plants are relatively brittle, easy to remove, and rarely have leaves attached at the base. As a result they rarely recover even when a portion of the stem is left intact.

Mechanical Treatment: Weedeaters or mowing can also be used effectively to treat yellow starthistle. Mowing too early, however, such as during the bolting stage will allow increased light penetration, more vigorous plant growth, and high seed production. Mowing is best when conducted at the spiny to early flower stage. Mowing after this period will not prevent seed production. In addition, mowing is successful only when the lowest branches of plants are above the height of the mower blades. Under this condition, recovery is minimized. Results should be repeatedly monitored, as additional mowing may be necessary to ensure reduced recovery and seed production.

Grazing: Yellow starthistle is nutritious and palatable to livestock after the flower stalks have bolted but prior to development of the spines, usually in May or June. Intensive grazing by sheep, goats, or cattle before the spiny stage (which coincides with seed ripening) but after bolting can reduce biomass and seed production in yellow starthistle. Grazing earlier, at the rosette stage, favors yellow starthistle development by eliminating competitive plants which do not regrow as quickly. Infestations should be monitored frequently to determine when the majority of plants have bolted. To be effective, large numbers of animals must be used for short durations

Grazing can be used alone or in conjunction with other control methods. Animals can be confined by temporary electric fencing or by an experienced stock manager with well-trained cattle-herding dogs. Because it takes skill and experience to determine stocking rates and to care for the animals properly, it is best to hire a handler with vegetation management experience. Since most defoliated yellow starthistle will recover from one grazing, it is necessary to graze two to four times at approximately two-week intervals under rotational grazing. Alternately, grazers can be left on-site for two to three months under a continuous grazing regimen.

Prescribed Burning: Under certain conditions, burning can provide effective control of yellow starthistle and enhance the survival of competing native forbs and perennial grasses. This can be achieved most effectively by burning after native species have dispersed their seeds but before yellow starthistle produces viable seed (June-July). Dried vegetation of senesced plants will serve as fuel for the burn. A follow-up management program will be essential to the long-term control of yellow starthistle; prescribed burning may be most appropriate as part of an integrated approach.

As with mechanical treatments, the success of prescribed burns depends on proper timing. The optimal time for burning is early to mid summer, which may not be feasible in some areas according to site-specific weather conditions. During this time starthistle is in the very early flowering stage and will not have produced viable seeds, whereas seeds of most desirable species will have already dispersed and grasses will have dried to provide adequate fuel.

Biological Control: Two insect species, hairy weevil (*Eustenopus villosus*) and false peacock fly (*Chaetorellia australis*), have proven to cause a significant level of seed destruction on yellow starthistle in California. The weevil was approved and released by the U.S. Department of Agriculture-Agricultural Research Service (USDA-ARS) Biological Control of Weeds Laboratory; the fly was not approved but was introduced accidentally. EBRPD has a well-established Yellow starthistle biological control program in 12 parks in Alameda and Contra Costa Counties.

Chemical Treatment: Although several non-selective pre-emergent herbicides will control yellow starthistle, few of these can be used in rangeland or natural ecosystems. The primary options for control in non-crop areas are post-emergent herbicides such as triclopyr, dicamba, and glyphosate. All

but glyphosate are selective and preferably applied in late winter or early spring to control seedlings without harming grasses. Once plants have reached the bolting stage, the most effective control can be achieved with glyphosate (1 percent solution). The best time to treat with glyphosate is after annual grasses or forbs have senesced, but prior to yellow starthistle seed production (May-June). The most effective compound for yellow starthistle control is clopyralid (as Transline®), a broadleaf selective herbicide. Clopyralid provides excellent control, both pre-emergence and post-emergence, at rates between 1.5-4 acid equivalent or 4-10 oz formulated product per acre. Although excellent control was achieved during testing with applications from December through April, earlier application/s led to significant increases in quantity of other forage species, particularly grasses.

East Bay Regional Park - Native Grass Seed Mixes

Contact David Amme, Range and Wildland Vegetation Program Manager

Regional Native Perennial Grass Mix #1 – 35 lbs per acre
This mix is combination of regional native perennial grasses and native annual clover primarily for upland, clay to loamy soil sites.

12 *Bromus carinatus* – East Bay Area Hills
6 *Hordeum brachyantherum* – East Bay Area Hills
8 *Elymus glaucus*, Berkeley Hills
4 *Nassella pulchra*, Purple Neddlegrass – Los Vaqueros
5 *Trifolium wildenovii*, Tom Cat Clover - Northern California Source

Regional Native Perennial Grass Mix #2 – 30 lbs per acre
This mix is combination of fast growing regional native perennial grasses and native annual clover primarily for fast cover and erosion control.

12 *Bromus carinatus* – East Bay Area Hills
6 *Hordeum brachyantherum* – East Bay Area Hills
8 *Elymus glaucus*, Berkeley Hills
4 *Trifolium wildenovii*, Tom Cat Clover - Northern California Source