CATALINA ISLAND'S INVASIVE PLANT MANAGEMENT PROGRAM, WITH AN EMPHASIS ON INVASION AND PROTECTION OF OAK ECOSYSTEMS

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ABSTRACT: Invasive species are considered one of the greatest threats to biodiversity and are the leading cause of species extinctions in island ecosystems; Catalina Island, California is no exception. The Catalina Island Conservancy, which owns and manages 88% of the 19,425-hectare island, has developed and implemented a comprehensive management program (Catalina Habitat Improvement and Restoration Program, CHIRP) to protect its unique ecosystems from priority invasive plant species. In 2003, an extensive island-wide invasive plant survey and analysis was conducted, and 76 non-native invasive plant species were mapped and prioritized for management action. Thirty-nine of these taxa were found to infest island scrub oak chaparral while nine invade island oak woodland. Not all 39 species that have invaded oak ecosystems are considered a serious threat to these systems, nor are they all being targeted. In 2004, the CHIRP program was initiated utilizing both a species-based and a site-based approach to prioritizing management actions, along with treatment along dispersal corridors, and prevention of new introductions. This combination of management approaches, based on extensive research data, has resulted in 43 priority invasive plant species being targeted for some type of management action: eradication (25 species), reduction (6 species), and control (12 species). Of the species being managed island-wide, 18 species are considered to be the most threatening to oak ecosystems. Although the Conservancy is addressing a large number of invasive plant species, annual grasses most likely impact oak ecosystems more than any other group of invasive plants; however, there are no cost-effective methods to reduce their abundance and they are consequently not being managed. Of the 76 species surveyed throughout the island, the alteration of fire regimes is suspected of being the greatest threat to oak ecosystems posed by this group of species. The Conservancy is actively working to reduce the impact of invasive plants on oak ecosystems. If the Conservancy is to outpace the threat that invasive plants pose to oak ecosystems, it will have to remain committed and continue to advance how it manages invasive species.

KEYWORDS: Catalina Island, invasive plant control, invasive plants, invasive species eradication, island scrub oak chaparral, land management, non-native, oak woodland

INTRODUCTION

The preservation and restoration of natural biodiversity is one of the key conservation challenges of our time (Reid and Miller 1989, Wilson 2002). After habitat loss, invasive species have been identified as the second greatest threat to the preservation of biodiversity worldwide and are likely to be the greatest contributor to species extinctions in island ecosystems (Clout and Veitch 2002). Catalina Island (Catalina), the third largest of the eight California Channel Islands, is no exception; over 240 non-native plant species (36% of the Island's flora), 76 of them identified as invasive, now threaten the Island's 422 native plant and 56 resident vertebrate species (including 39 taxa endemic to one or more California Islands) and it's unique habitats. Catalina is home to six federally listed threatened or endangered plant and animal species, four of which have been identified as being threatened with extinction by invasive plants (U.S. Government 2004).

Island scrub oak chaparral, dominated by *Quercus pacifica*, is endemic to three of the California Channel Islands. *Q. pacifica* is listed as globally vulnerable (NatureServe 2008), and is a dominant vegetation type on Catalina (23%, Knapp 2002). Island Oak Woodland is dominated by *Quercus tomentella*, which is considered the rarest oak in North America (Pavlik et al. 1992), and is also listed as vulnerable (NatureServe 2008). *Quercus tomentella* is endemic to five California Channel Islands as well as Guadalupe Island (Baja CA, Mexico). It is found in eight locations on Catalina, covering less than one percent of the island (Knapp 2002, Knapp this volume), and inhabits steep, north- and west-facing rocky slopes. Both oak ecosystems are invaded by a suite of invasive plants that directly and indirectly impact these systems by altering understory vegetation structure and composition, increasing fire frequency and flammability, altering oak ecosystem food webs, and by competing with oaks and associated species for water, light, and nutrients.

For more than a decade the Catalina Island Conservancy (Conservancy), which owns and manages 88% of the 19,425-hectare island, has pursued an active and science-based conservation program aimed at restoring the Island ecosystems. Control programs have been conducted to protect the island's ecosystems from the impacts of introduced ungulates. The Conservancy has nearly removed all feral goats (*Capra hircus*) and nearly all feral pigs (*Sus scrofa*) from the Island, culls the Island's herd of introduced American bison (*Bison bison*), and controls the heard of mule deer (*Odocoileus hemionus*) through a private lands management program through the California Department of Fish and Game.

Invasive plant survey results have indicated that the abundance and distribution of invasive plants on Catalina is much worse than originally thought. The Conservancy is witnessing an enormous population expansion of several highly ranked invasive plant species on the west end of the Island where bison have been excluded for almost 15 years and the feral animal removal program first began over two decade ago. Although essential to the recovery of the Island, these animal control programs appear to have released some invasive plant species from grazing and browsing pressure, and the Conservancy believes that this is a precursor of what is to come following the complete eradication and reduction of introduced ungulates from the East End (86%) of Catalina. In the 1990's following the removal of cattle and feral sheep from Santa Cruz Island, fennel populations exploded from hundreds to thousands of acres within a brief period of time (Peter Schuyler, personal communication 2004). To address this conservation challenge, the Conservancy developed the Catalina Habitat Improvement and Restoration Program (CHIRP) in order to protect the Island's natural resources from the impacts of invasive plants. This paper discusses the strategies of the CHIRP, the plants that are actively managed, and the methods used to control them, while offering insight into the current and future challenges to protect oak ecosystems from invasive plants.

DISCUSSION

Mapping and planning

The *Catalina Invasive Plant Ranking Plan* (Knapp 2004) provided the Conservancy with an excellent understanding of the scope of the invasive plant problem on the Island in 2003 and 2004, and laid the scientific foundation for implementing the CHIRP. Seventy-six high priority invasive plants were identified, and 37,208 invasive plant populations were mapped with a global positioning system and stored in a geographic information system (GIS) database. Two hundred and thirty-three major drainages and approximately 220 ridgelines (724 km) were surveyed on foot, while 354 kilometers of roads were surveyed by four-wheel drive vehicle and 84 kilometers of coastline were surveyed by boat or helicopter. This totals over 1,046 kilometers of transects surveyed. A literature review of the biological characteristics as well as the ecological preferences of each invasive species was conducted, and an investigation into the available control knowledge and technology for each species was completed. All 76 species were ranked for management priority as High, Moderate, or Limited using the California Invasive

Plant Council plant assessment form (Cal-IPC 2006), based on their ecological impacts, invasiveness, abundance and distribution on Catalina, and their ease of control. Species that do not impact wildlands or for which there was very little documentation were assigned a rank of Not Listed. Species that were not prioritized were placed in the category of Not Ranked. Forty-three of the 76 invasive plant species surveyed have been targeted for management (Table 1), 18 of which threaten oak ecosystems.

The most problematic invasive plant species may be those that were not surveyed for: non-native annual grasses. These species are ubiquitous on the Island, and are known to impact oak ecosystems throughout California by utilizing water faster than native oak seedlings and impeding oak seedling survival (Gordon et al. 1989, McCreary 1990, Danielson and Halvorson 1991, Gordon & Rice 2000). Currently, there is no cost-effective option to manage non-native annual grasses at the landscape level. Control techniques do exist to manage other priority invasive plants threatening oak ecosystems, however, which is the basis for CHIRP.

The CHIRP

The CHIRP has four strategies: 1) a species-based and 2) site-based approach, 3) control along roads and trails, and 4) prevention of new invasions. Each of these strategies is described below.

Rejmanek and Pitcairn (2002) showed that population eradication success decreases exponentially and the amount of control effort increases exponentially with an increase in population size. They found that populations less than 0.08 hectares had nearly 100% eradication success, and that populations one hectare and greater had nearly no eradication success. Species that have small populations are much easier to eradicate than larger ones due both to fewer above-ground individuals as well as a limited extent of the soil seed bank. In keeping with these findings, highly-ranked invasive plant species with limited distributions and high potential impacts are being controlled to zero density on Conservancy property in the species-led approach with the ultimate goal of eradication. These species are known to be highly invasive elsewhere and are poised to spread in similar ecosystems on Catalina. At present, since they are relatively limited in their abundance on the Island, their impacts may not be readily evident. Yet if left unmanaged they will continue to expand as they have done elsewhere, causing more costly problems to solve later. Eradicating these species now will ensure that they do not negatively affect listed native species or unique ecosystems dominated by oaks (Figure 1) in the future.

Figure 1. Island scrub oak chaparral dominates the Channel side of the Island where the major coves are inhabited by various educational youth camps. Unfortunately, these coves are landscaped with invasive plants, and are foci for future plant invasions that may pose a threat to oak ecosystems.

Table 1. Invasive plant species ranked for Island-wide management (legend on following page)

Species	Common Name	Threat Rank	Control Rank
*Acacia melanoxylon****	Blackwood acacia	Moderate	B
*Ailanthus altisisma**	Tree-of-Heaven	Moderate	A
*Aptenia cordifolia**	Baby sun-rose	Not Listed	B
*Arundo donax**	Giant cane	High	A
*Asparagus asparagoides**	Bridal creeper	High	A
*Cakile maritime**	Sea rocket	Moderate	B
*Carduus pycnocephalus***	Italian thistle	Moderate	B
*Carpobrotus edulis****	Hottentot-fig	High	B
*Centaurea solstitialis**	Yellow star thistle	High	A
*Centranthus ruber**	Red valerian	Not Listed	B
*Cortaderia selloana**	Pampas grass	Moderate	B
*Cynara cardunculus**	Artichoke thistle	Moderate	A
*Delairea odorata**	Cape ivy	High	A
*Ehrharta calycina**	Veldt grass	High	B
*Eriogonum fasciculatum**	California buckwheat	Not Ranked	A
*Eucalyptus camaldulensis****	River red gum	Limited	B
*Festuca arundanceae****	Tall fescue	Moderate	A
*Ficus carica**	Fig tree	Moderate	B
*Foeniculum vulgare***	Fennel	High	C
*Genista linifolia***	Flax-leaved broom	High	C
*Genista monspessulana****	French broom	High	B
*Hedera helix**	English ivy	Moderate	A
*Lathyrus odoratus**	Sweet pea	Not Listed	A
Lyonothamnus floribundus ssp. *asplenifolius**	Fern-leaf ironwood	Not Ranked	A
*Marrubium vulgare****	Horehound	Moderate	C
*Mesembryantemum crystallinum****	Crystaline ice plant	High	B
*Nicotiana glauca****	Tree tobacco	Moderate	C
*Opuntia ficus-indica****	Mission cactus	Not Ranked	A
*Pelargonium x hortorum****	Garden geranium	Not Listed	B
*Phalaris aquatica***	Harding grass	High	C
*Phoenix canarinesis****	Canary Island date palm	Moderate	B
*Pinus halepensis***	Aleppo Pine	High	B
*Pittosporum undulatum**	Mock orange	High	B
*Ricinus communis**	Castor bean	Moderate	A
*Rubus discolor**	Himalayan blackberry	High	A
*Salsola tragus***	Russian thistle	Moderate	B
*Schinus molle****	Peruvian pepper	Limited	B
*Senna didymobotria**	African senna	Limited	A
*Silybum marianum**	Milk thistle	Moderate	B
*Spartium junceum**	Spanish broom	High	A
*Tamarix ramosissima**	Salt cedar	High	A
*Tetragonia tetragoniodes**	New Zealand spinach	Not Ranked	A
*Vinca major**	Periwinkle	High	A

Table 1 Legend

Management Objective: Eradication: * = 25, Reduction: ** = 6, and Control (ad hoc): *** = 12
High = severe ecological impacts on physical processes, plant and animal communities, and vegetation structure. Their reproductive biology and other attributes are conducive to moderate to high rates of dispersal and establishment. Most are widely distributed ecologically.
Moderate = substantial and apparent—but generally not severe—ecological impacts on physical processes, plant and animal communities, and vegetation structure. Their reproductive biology and other attributes are conducive to moderate to high rates of dispersal, though establishment is generally dependent upon ecological disturbance. Ecological amplitude and distribution may range from limited to widespread.
Limited = ecological impacts are minor on a statewide level or there was not enough information to justify a higher score. Their reproductive biology and other attributes result in low to moderate rates of invasiveness. Ecological amplitude and distribution are generally limited, but these species may be locally persistent and problematic.
Not Listed = species that either have a significant lack of documentation to be ranked, or species that have been determined not to be invasive to wildlands.
Not Ranked = species that have not be prioritized for impacts or invasiveness.

The second strategy of the program is to take a site-based approach by managing widespread invasive plant species at the watershed level (Knapp and Knapp 2005). By dividing the Island into 105 habitat management units based on major watersheds, the Conservancy has prioritized management efforts based on the extent of high value natural resources found within each management unit and the invasive plant infestations threatening them. This allows the Conservancy to utilize limited resources effectively by focusing on key resource sites, where widespread species are targeted for either strategic reduction or ad hoc control. The goal of reduction is to strategically limit the abundance of a species in a defined area, whereas the objective of ad hoc control is limited to eliminating a select number of plants on-site, with little change to the overall abundance of the population.

For each targeted population, regardless of the island-wide management objective, the Conservancy actively removes all above-ground plants to zero density. Once all plants have been removed or treated, the population seed bank is monitored for seedlings or resprouts. Consistent monitoring and immediate treatment is important to maintain the benefits derived from the initial treatment. Some species' life cycles necessitate multiple monitoring surveys throughout the growing season, while others require only one inspection. The goal for all targeted populations is local eradication, regardless if the species is identified for eradication or reduction. The third strategy is to control populations of species targeted for eradication or reduction found along roadsides. Removing populations from transportation corridors is vital to limiting the spread of priority invasive plant species to high-value ecosystems such as island scrub oak chaparral, which is commonly found adjacent to roads throughout the Island.

The fourth strategy of the CHIRP program is to prevent either the introduction of new species to the Island or the spread of existing ones to new locations. Prevention is the most cost-effective invasive plant management option available (Bartuska 2003). The Conservancy recognizes that this is a key component to an integrated invasive plant management program; however, there is currently a lack of resources devoted to prevention. Once prevention elements are developed and put in place, the influx of new species to the Island and the dispersal from Avalon and Two Harbors to the Interior can be reduced and regulated.

Invasive plants in Catalina's oak ecosystems

Thirty-nine invasive plant species (Table 2) infest at least 85 hectares of *Q. pacifica* chaparral among 4,720 populations (Knapp 2004). Although only 1.9% of the oak ecosystem is infested, invasive species by nature will continue to expand at a cost to oaks and associated species The five most common species

Table 2. Invasive plant species infesting Island scrub oak chaparral

Species	Net Area Infested (sq. m.)
*Nicotiana glauca****	263,200
*Genista linifolia***	168,400
*Foeniculum vulgare***	99,700
*Marrubium vulgare****	91,408
*Carduus pycnocephalus***	70,614
*Piptatherum miliaceum*****	38,049
*Genista monspessulana****	29,163
*Phalaris aquatica***	27,871
*Brassica spp.*****	26,487
*Cynodon dactylon*****	11,002
*Ehrharta calycina**	5,055
*Vicia villosa*****	2,235
*Cirsium vulgare****	2,187
*Silybum marianum**	1,384
*Xanthium spinosum*****	863
*Eucalyptus camaldulensis****	596
*Schinus molle****	403
*Salsola tragus****	335
*Oxalis pes-caprae****	252
*Pelagonium Xhortorum****	240
*Lactuca saligna*****	194
*Cortaderia selloana**	192
*Atriplex semibaccata*****	128
*Ricinus communis**	116
*Ficus carica**	82
*Rorippa nasturtium-aquaticum*****	76
*Mesembryanthemum crystallynum****	37
*Asparagus asparagoides**	34
*Cynara cardunculus**	28
*Phoenix canariensis****	18
*Hedera helix**	16
*Lathyrus odoratus*****	11
*Digitaria sanguinalis*****	11
*Pinus halepensis***	3
*Lactuca serriola*****	2
*Raphanus spp.*****	0.37
*Eucalyptus globulus****	0.28
*Acacia melanoxylon****	0.09
*Tamarix ramosissima**	0.09

Management Objective: Eradication = *, Reduction = **, Control (ad hoc) = ***, and No control = *****

include: *Nicotiana glauca*, *Genista linifolia*, *Foeniculum vulgare*, *Carduus pycnocephalus*, and *Marrubium vulgare*. Of these species, *C. pycnocephalus*, *G. linifolia*, and *F. vulgare* are known to be highly invasive and to have the greatest ecosystem impacts (Table 3), such as altering fire regimes or vegetation structure, and competing with native species. All three species have a wide-range of environmental preferences, which contribute to their ability to invade the various microclimates that oaks inhabit.

Table 3. Invasive plant species and known or suspected impacts to oak ecosystems

Species	Impact
Acacia melanoxylon	*Alters soil chemistry, and competes with native species*
Asparagus asparagoides	*Alters fire regime, and competes with native species*
Carduus pycnocephalus	*Alters understory and fire regime, and outcompetes native species*
Cortaderia selloana	*Alters understory and fire regime, and outcompetes native species*
Cynara cardunculus	*Alters understory and fire regime, and outcompetes native species*
Delairea odorata	*Alters vegetation structure and topples oaks*
Ehrharta calycina	*Alters understory and competes with native species*
Eucalyptus camaldulensis	*Alters overstory, soil chemistry, fire regime, and hydrology, and competes with native species*
Festuca arundanceae	*Alters understory and fire regime, and competes with native species*
Genista linifolia	*Alters understory, soil chemistry, and fire regime, and competes with native species*
Genista monspessulana	*Alters understory, soil chemistry, and fire regime, and competes with native species*
Hedera helix	*Alters vegetation structure and topples oaks*
Pinus halepensis	*Alters overstory, and excludes understory species*
Piptatherum miliaceum	*Alters understory and competes with native species*
Rubus discolor	*Alters understory and competes with native species*
Silybum marianum	*Alters understory and fire regime, and competes with native species*
Spartium junceum	*Alters understory, soil chemistry, and fire regime, and competes with native species*
Vinca major	*Alters understory and competes with native species*

Forty-eight populations comprised of of nine invasive plant species (Table 4) infest over 0.6 hectares of *Q. tomentella* woodland (Knapp 2004). As with island scrub oak ecosystems, the amount of Island oak ecosystems invaded (0.3%) is minimal; however, if left unchecked, these and other species may increase in abundance and impact. The three most common species include: *N. glauca*, *Vicia villosa*, and *Cirsium vulgare*. All species infesting *Q. tomentella* woodland are also found within *Q. pacifica* chaparral. All of the invasive plants that can invade *Q. pacifica* chaparral are expected to be able to invade *Q. tomentella* woodland; however, these species have either not yet dispersed to the limited and disjunct *Q. tomentella* woodland systems, or are outcompeted by other more competitive invasive plant species.

It is not surprising that *N. glauca* is the most common invasive perennial species in oak ecosystems since it is the most well distributed invasive plant species on the Island, with 5,675 populations. However, this species rarely forms dense infestations. Of the 39 species surveyed that infest oak ecosystems, broom species (*G. linifolia, G. monspessulana,* and *Spartium junceum*) are expected to be more threatening than other invasive plants due to their ability to alter ecosystem processes such as soil nutrient cycling and fire regimes, as well as their ability to form dense monostands and outcompete native plants for light and

Table 5. Control methods to treat priority invasive plant species

Table 4. Invasive plants infesting Island oak woodland

Species	Net Area Infested (sq. m.)
*Nicotiana glauca****	2,450
*Vicia villosa*****	2,118
*Cirsium vulgare****	893
*Marrubium vulgare****	138
*Piptatherum miliaceum*****	67
*Foeniculum vulgare***	3.5
*Cynodon dactylon*****	1.5
*Carduus pycnocephalus***	0.28
*Ficus carica**	0.28

Management Objective: Eradication = *, Reduction = **, Control (ad hoc) = ***, and No control = *****

water (Knapp 2004) (Figure 2). Thistle species (*C. pycnocephalus*, *Cynara cardunculus*, and *Silybum marianum*) are of concern as well, since they produce copious amounts of seeds (in excess of 10,000 seeds per mature plant) that are wind dispersed (Figure 2). These species can form large monotypic stands very quickly throughout the oak understory. Invasive plant species that are being managed due to their known and suspected impact to oak ecosystems are presented in Table 4.

Figure 2a-c. Broom species such as *Genista linifolia* (a) can alter soil chemistry and can grow in full sunlight or in the shaded canopy of oaks. *Carduus pycnocephalus* (b) can form large monotypic stands between and under oaks that can carry fire from the ground into the oak canopy. Thistles such as *Cirsium vulgare* (c) and *C. pycnocephalus*, and broom species can produce over 10,000 viable seed per adult plant each season.

Control methods

A variety of treatment methods (Table 5) are utilized to treat priority invasive plant species throughout the Island. Chemical control is primarily used to treat species that threaten oaks due to the habitat impact associated with mechanical and physical control methods, including trampling by multiple workers and volunteers. Chemical control has proven to be the most cost-effective method as well.

Species	Treatment Method(s)
Acacia melanoxylon	Cut-stump or drill-n-fill 100% Triclopyr
Ailanthus altisisma	Drill-n-fill 100% Triclopyr or Glyphosate
Aptenia cordifolia	Hand-pull
Arundo donax	Cut-stump 100% Glyphosate
Asparagus asparagoides	Excavate ryhzomes
Cakile maritime	Hand-pull
Carduus pycnocephalus	Foliar Clopyralid
Carpobrotus edulis	Hand-pull
Centaurea solstitialis	Hand-pull
Centranthus ruber	Foliar 5% Glyphosate
Cortaderia selloana	Foliar 5% Rodeo or Glyphosate
Cynara cardunculus	Foliar Clopyralid or 5% Glyphosate
Delairea odorata	Foliar 0.5% Triclopyr
Ehrharta calycina	Foliar 2% Glyphosate
Eriogonum fasciculatum	Cut-stump 50% Glyphosate
Eucalyptus camaldulensis	Cut-stump or drill-n-fill 100% Glyphosate
Festuca arundanceae	Hand-pull, foliar 2% Glyphosate
Ficus carica	Basal bark 13.3% Triclopyr, drill-n-fill 100% Triclopyr
Foeniculum vulgare	Foliar 0.5, 1, or 2% Triclopyr*, excavate tap root
Genista linifolia	Cut-stump 50% Glyphosate, Weed Wrench™
Genista monspessulana	Cut-stump 50% Glyphosate, Weed Wrench™
Hedera helix	Cut-stump 100% Glyphosate or Triclopyr
Lathyrus odoratus	Foliar Clopyralid
Lyonothamnus floribundus ssp. *asplenifolius*	Basal bark 13.3% Triclopyr, drill-n-fill 100% Triclopyr
Marrubium vulgare	Foliar 5% Glyphosate
Mesembryantemum crystallinum	Hand-pull
Nicotiana glauca	Cut-stump 50% Glyphosate, basal bark 13.3% Triclopyr
Opuntia ficus-indica	Drill-n-fill 100% Glyphosate
Pelargonium x hortorum	Hand-pull or foliar 5% Glyphosate
Phalaris aquatica	Foliar 2% Glyphosate
Phoenix canarinesis	Drill-n-fill 100% Glyphosate
Pinus halepensis	Cut-stump 100% Glyphosate
Pittosporum undulatum	Drill-n-fill Triclopyr
Ricinus communis	Basal bark 13.3% Triclopyr, Cut-stump 100% Triclopyr
Rubus discolor	Foliar 2% Triclopyr or 5% Glyphosate, Cut-stump 100%
Salsola tragus	Foliar 5% Glyphosate
Schinus molle	Drill-n-fill 100% Triclopyr
Senna didymobotria	Cut-stump 100% Triclopyr
Silybum marianum	Foliar Clopyralid
Spartium junceum	Cut-stump 50% Glyphosate, Weed Wrench™
Tamarix ramosissima	Basal bark 13.3% Triclopyr, cut-stump or drill-n-fill 100% Triclopyr
Tetragonia tetragoniodes	Hand-pull
*Vinca major**	Foliar 5% Glyphosate

Comments: Aminopyralid (Milestone VM) is now the preferred herbicide to Clopyralid (Transline) & CMR

Canhance is an aquatic approved surfactant mixed with Clopyralid, Glyphosate, & Triclopyr

Mechanical/Physical Control

Mechanical control methods such as chopping, grubbing, cutting, girdling, or mowing are used on species that do not resprout, or stands of annual grasses. These methods utilize a wide array of hand and power tools, including: weed wrenches, loppers, handsaws, brush cutters, chain saws, and power hedgers.

Chemical Control

Use of herbicides is utilized when mechanical or physical techniques are not effective alone or when they create unacceptable collateral consequences to the native habitat. Whenever feasible, techniques such as cut-stump, drill-and-squirt, hack-and-squirt, glove-of-death, and basal bark application are used to reduce drift and the amount of herbicide used. Herbicides with the lowest EPA rating ("caution") are used to minimize the risk to the applicator. Selective herbicides are used to treat populations of invasive dicots where native monocots are present. Selective herbicide effective only on thistles (Asteraceae) or herbaceous taxa in the pea family (Fabaceae) are used as well. Very low rates of a non-selective herbicide are used to treat invasive plants found invading robust perennial native vegetation, which causes virtually no harm to non-target native plants. Herbicides that pose the least amount of risk to the environment are utilized as well.

The three main herbicide delivery systems used are truck-mounted spray rigs, backpack sprayers, and spray or squeeze bottles. Truck-mounted spray rigs are used when treating along roadsides and in areas with high densities of the target species. Small populations or those found further than the length of the spray rig hose (189 meters) are usually treated with herbicide contained in a backpack sprayer or 15 milliliter handheld spray or lab-style squeeze bottles transported in backpack dry-bags. The most effective delivery system is the handheld bottles, which allow the applicator to easily move along steep slope and through the maze of low-hanging oak branches. Backpack sprayers are often very cumbersome, and do not allow the applicator to move through the infestation freely.

CONCLUSION

A range of invasive plant species infest endemic oak ecosystems and threaten them to varying degrees on Catalina Island. The greatest threat to these ecosystems by the invasive plant species surveyed appears to be their ability to act as ladder fuels, carrying fire into the canopy of oaks. Short fire return intervals can also impact the survival of oak stands, if the time between fire is not long enough for trees to resprout and replenish underground energy stores (Zedler 1995, Keeley 2000, Witter et. al 2007). Many invasive plant species such as *F. vulgare*, *G. linifolia*, and non-native annual grasses have a positive response after fire, and may subsequently impact oaks further. Perennial non-native plants tend to be less palatable to non-native herbivores, and may expand following a fire at the expense of browsed oaks and associated native plant species. Impacts caused by invasive plants may have more lasting affects on a system that has been disturbed.

Integrated control methods, such as using volunteers to manually remove plants or combining chemical and manual techniques, are used to address invasive plants on Catalina, but due to the large number of species found throughout the island, chemical control is the cheapest and fastest method to safely make significant headway in turning the tide of invasion. Focusing management efforts on what is feasible while working towards developing realistic strategies and methods to address annual grasses (Figure 3) may be the most viable option available to the Conservancy at this time to manage invasive plant impacts in oak ecosystems. Recent advancements in weed management in California utilizing small two-person

helicopters to transport applicators to infestations has proven to be a cost-effective way to greatly eliminate access time and speed up remote species eradications (Knapp et al. in prep.). Consistently

Figure 3. Non-native annual grasses (understory) can impact oak regeneration by out competing seedlings for moisture, and causing cotyledon desiccation as acorns germinate under a thick mat of dry grass litter.

working to develop creative control methods and strategies, and resourcefully dealing with the constraints of island living will undoubtedly continue to enhance the effectiveness of the CHIRP.

Facing a suite of invasive plant species at various levels of abundance is similar to fighting a war on multiple fronts, resulting in diluting already scarce resources. It is much more difficult to address multiple species than to tackle only one or two, because a myriad of tools and techniques is required, along with extensive planning and operational flexibility. Eradicating invasive species that affect oak ecosystems, as is currently being done, may have an additive effect which will allow oak systems to persist on Catalina. In time, the Conservancy will be left to actively manage only a handful of problematic species, while maintaining a vigilant eye on the seed banks of eliminated above ground populations and new invaders.

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