Five-Year Comparison of Invasive Plant Helicopter Surveys for the Central Reserve of the Nature Reserve of Orange County

Report for the Natural Communities Coalition
By the California Invasive Plant Council
February 20, 2019

Background and Purpose

In 2011, the Irvine Ranch Conservancy (IRC) and Orange County Parks (OCP) sponsored a helicopter survey for invasive plants in the Central Reserve and adjacent open space. In 2016 and 2017, the Natural Communities Coalition with support from IRC, OCP and The Nature Conservancy supported a second survey of invasive plants by helicopter survey in the same area. These two surveys provide an opportunity to gauge change in invasive plant cover over the intervening five years, the effectiveness of invasive plant control efforts, and the utility of aerial mapping. Mapping from the air provides access to remote areas not easily accessible on the ground, and it covers a lot of territory quickly. Managers want to see whether such surveys can document landscape-scale changes in abundance and distribution of invasive plants and the impact of control work performed.

The two helicopter surveys were conducted by different companies using similar techniques but with different observers. Data were recorded using slightly different methodologies, so comparisons were not as straightforward as would be ideal. However, there was substantial overlap in survey area and species mapped, providing ample room for analysis. Figures 1-3 shows the flight lines from each survey and the overlap across both surveys. Figure 4 shows the area of overlap with additional areas avoided due to ground impediments in 2016/2017.

Not all areas were covered in each survey—see maps below—and not all plant species were mapped by each survey. Table 1 below shows the plant species surveyed in each year. In this report we focus on assessing the change in area for those species surveyed in both 2011 and 2016/17 across the entire survey area. However, we also briefly discuss the potential relevance of species mapped in one year and not the other. Our analysis omits species that were so widespread that they could not be comprehensively mapped in either survey such as Italian thistle (*Carduus pycnocephalus*) and milk thistle (*Silybum marianum*).

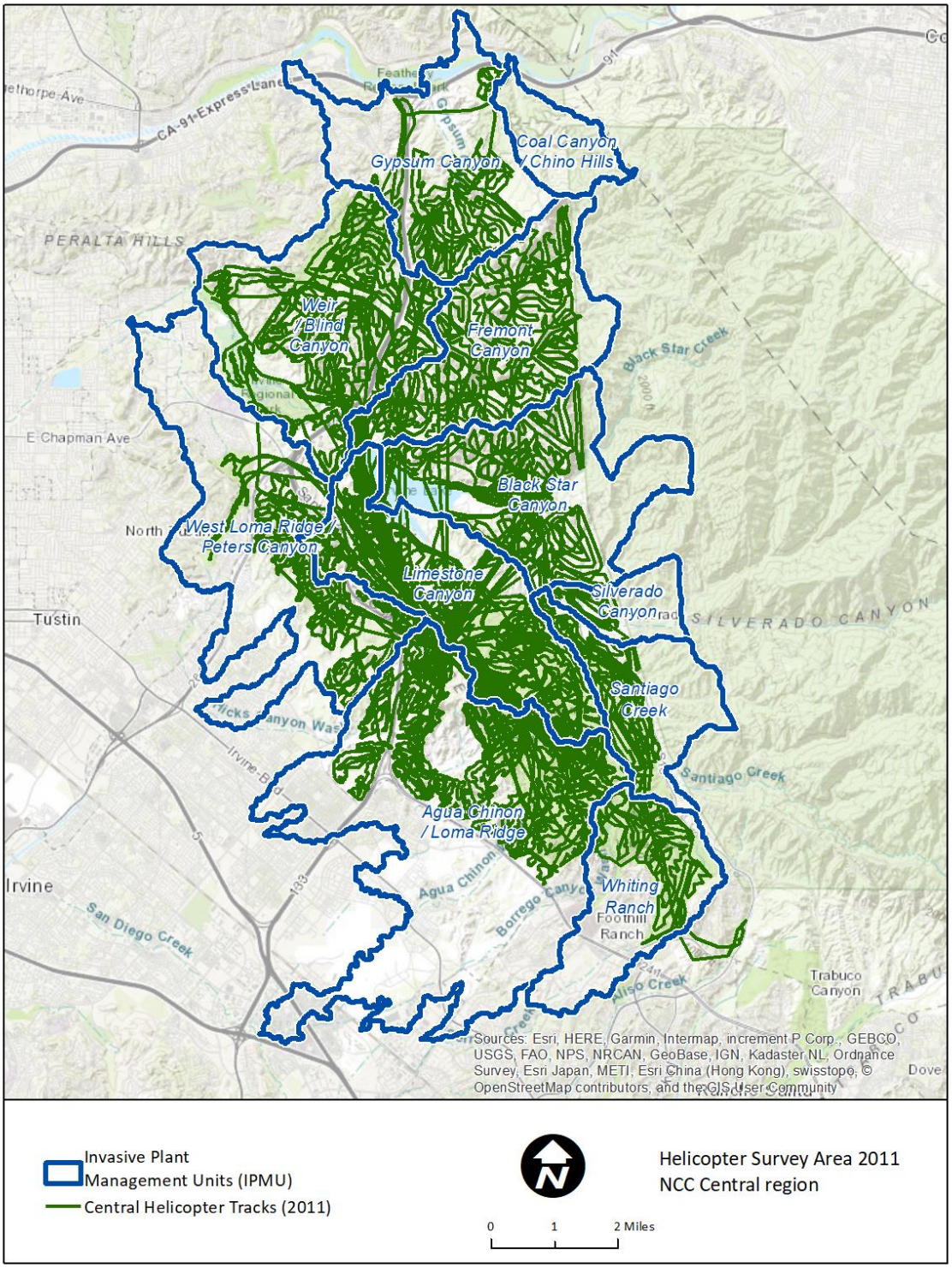

Figure 1. Central Reserve with area covered by 2011 helicopter survey (flight tracks shown in green).

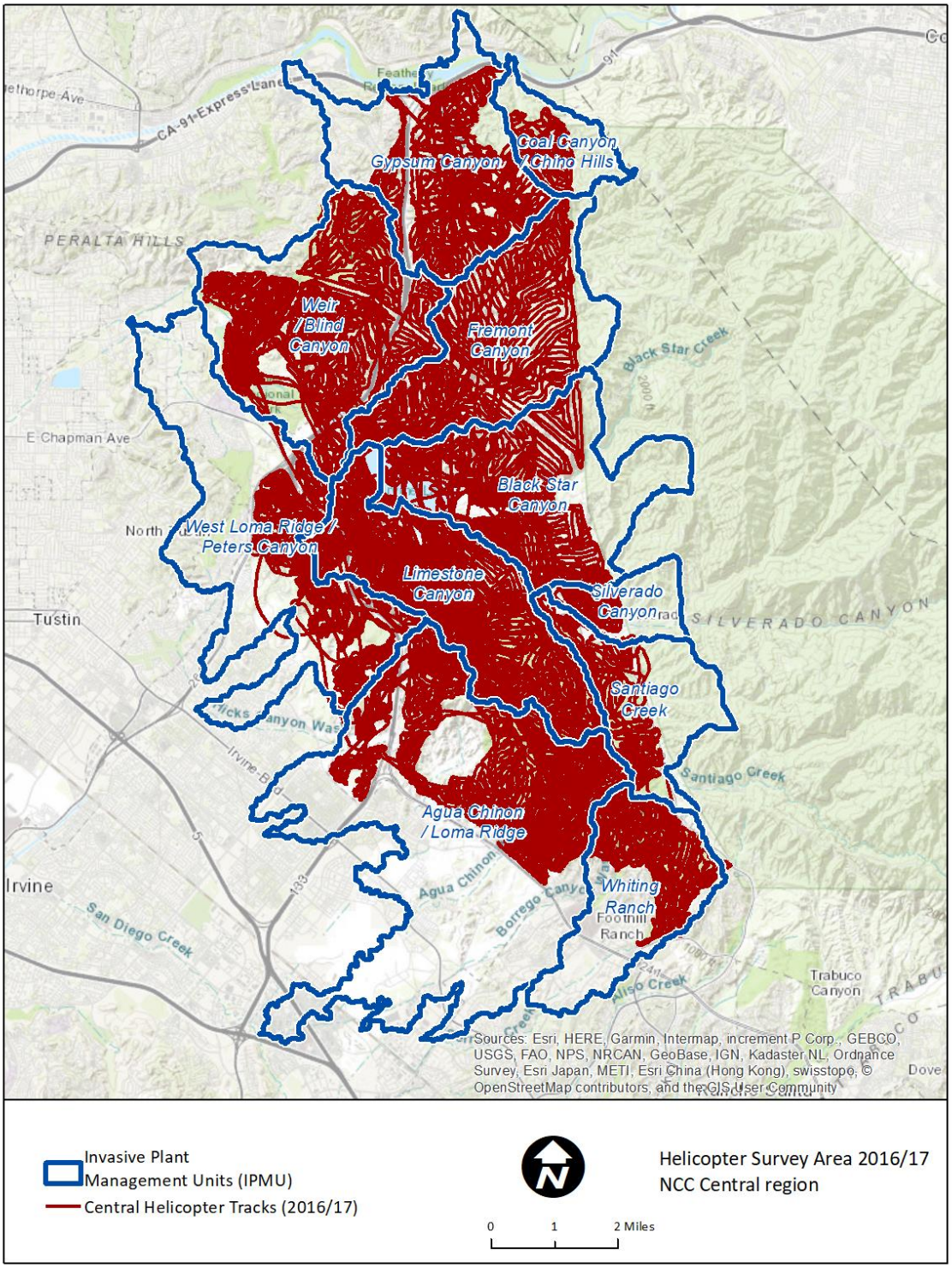

Figure 2. Central Reserve with area covered by 2016/2017 helicopter survey (flight tracks shown in red).

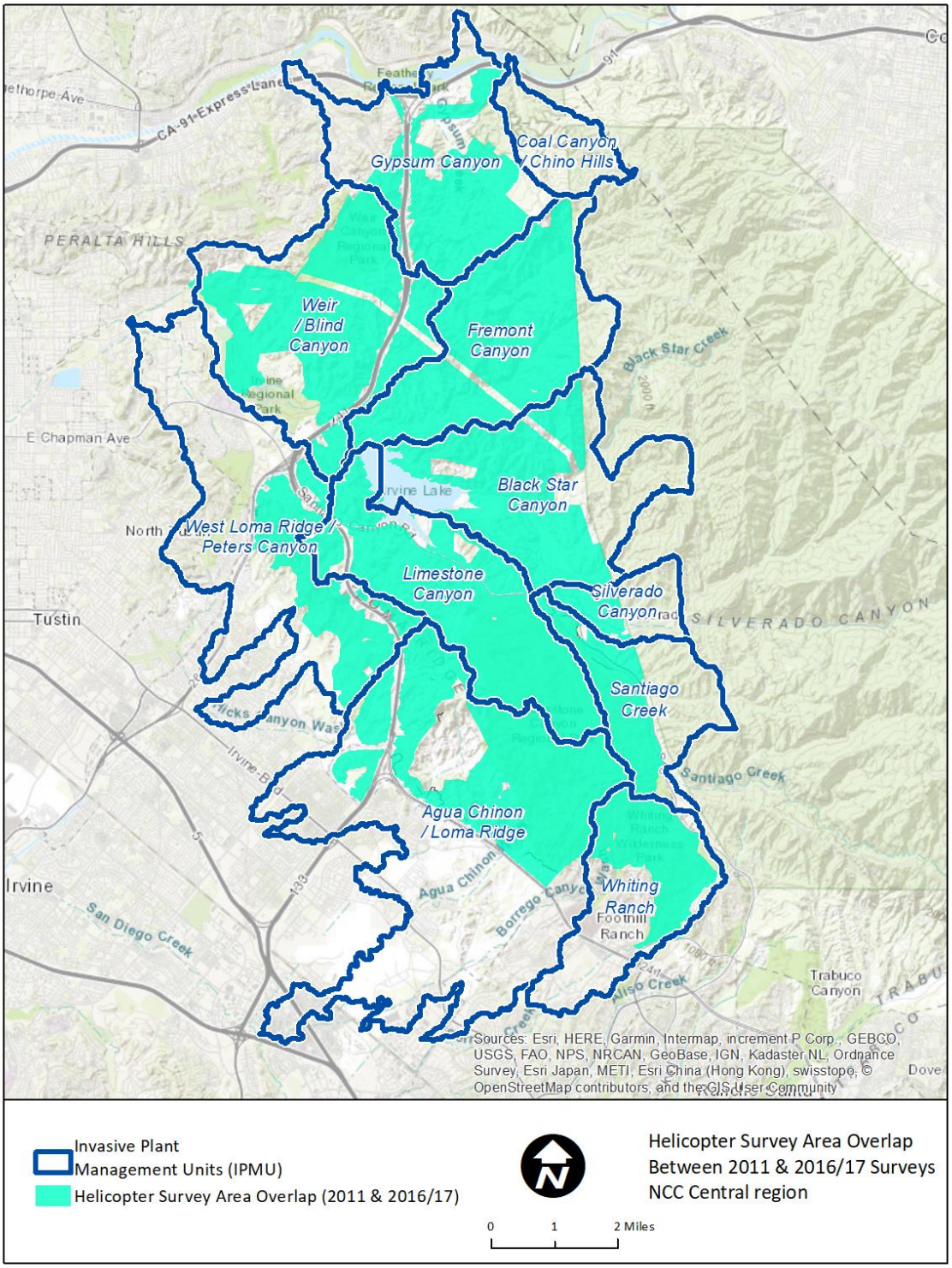

Figure 3. Central Reserve with area covered by both helicopter surveys.

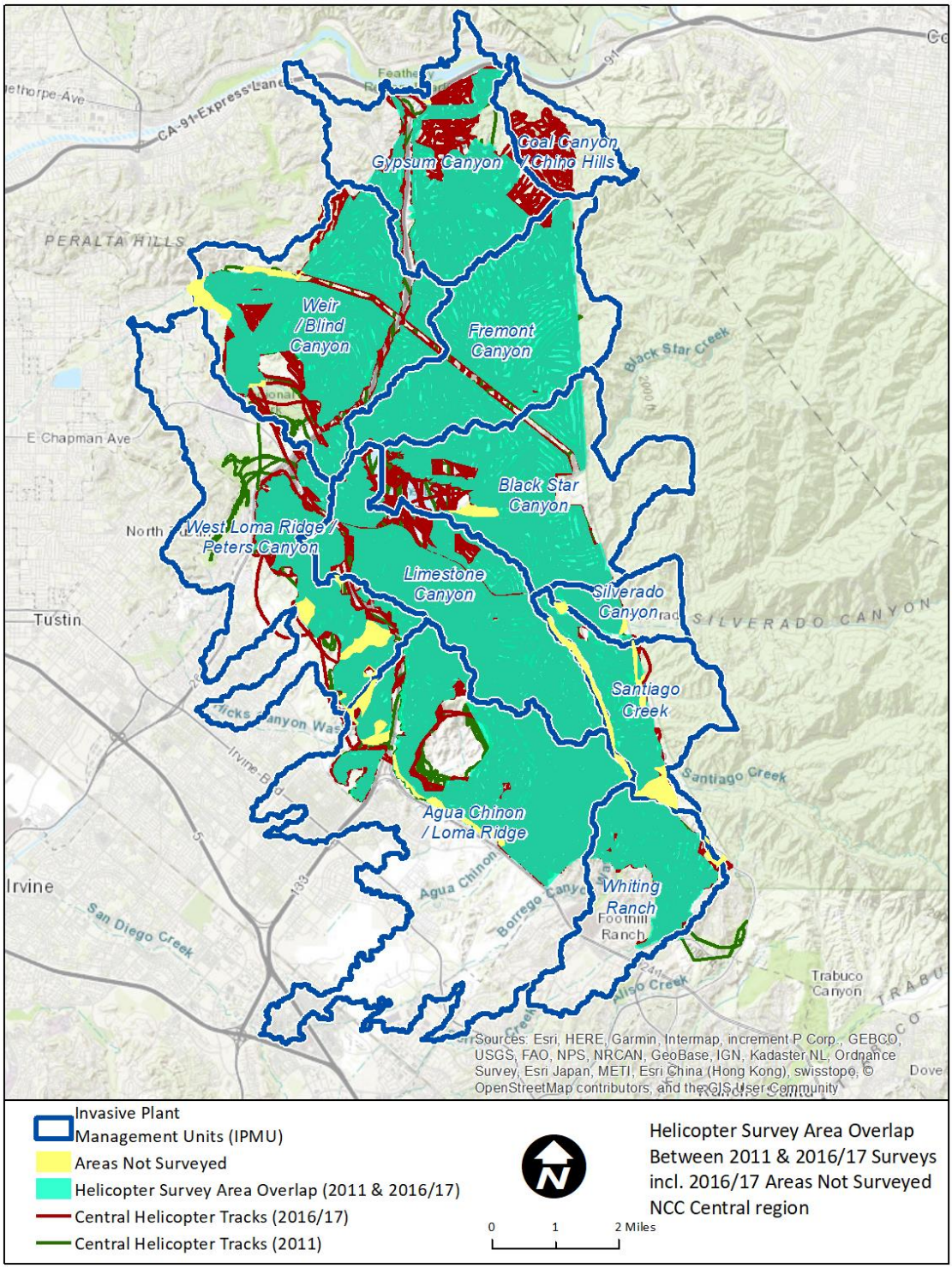

Figure 4. Central Reserve with area covered by both helicopter surveys showing areas marked "not surveyed" in the 2016/17 survey effort. These areas were included in the comparison—see discussion of methods.

Table 1. Species mapped by each helicopter survey. From Knapp (2011) final report to IRC and Ball (2017) final data to NCC.

Scientific Name	Common Name	2011	2016/17
Acacia sp.	acacia		Yes[¥]
Agave sp.	century plant		Yes
Ailanthus altissima	tree-of-heaven	Yes	Yes
Albizia lophantha	plume acacia	Yes	Yes[¥]
Arundo donax	giant reed	Yes	Yes
Asphodelus fistulosus	onionweed		Yes
Atriplex semibaccata	Australian saltbush	Yes	Partial
Carduus pycnocephalus	Italian thistle	Partial[*]	Partial[*]
Centaurea solstitialis	yellow starthistle	Yes	Yes
Cirsium vulgare	bull thistle	Yes	Yes
Conium maculatum	poison hemlock	Yes	Yes
Cortaderia selloana	pampasgrass	Yes	Yes
Cynara cardunculus	artichoke thistle	Yes	Yes
Ehrharta erecta	panic veldtgrass	Yes	™
Emex spinosa	spiny emex	Yes	™
Encelia farinosa	brittlebush	Yes	Yes
Eucalyptus spp.[+]	eucalyptus	Yes	Partial[*]
Ficus carica	edible fig		Yes
Foeniculum vulgare	fennel	Yes	Yes
Gazania linearis	gazania	Yes	Yes
Glebionis coronarium	garland chrysanthemum	Yes	Yes
Lepidium latifolium	perennial pepperweed	Yes	Yes
Limonium perezii	statis	Yes	
Limonium ramosissimum[!]	Algerian sea lavender		Yes
Marrubium vulgare	horehound	Yes	Yes
Myoporum laetum	ngaio tree	Yes	Yes
Nerium oleander	oleander	Yes	Yes
Nicotiana glauca	tree tobacco	Yes	Yes
Olea europaea	olive		Yes
Opuntia ficus-indica	nopal prickly pear		Yes
Parkinsonia sp.	[Mexican] palo verde		Yes
Pennisetum clandestinum	kikuyugrass		Yes[¥]
Pennisetum setaceum	crimson fountain grass	Yes	Yes
Phoenix canariensis	Canary Island date palm	Yes	Yes
Pinus sp.[#]	pine sp.	Yes	Yes
Piptatherum miliaceum	smilo grass	Yes	Partial[*]
Pittosporum undulatum	Victorian box	Yes	
Ricinus communis	castor bean	Yes	Yes
Robinia pseudoacacia[!]	black locust		Yes
Schinus molle	Peruvian peppertree	Yes	Yes

Schinus terebinthifolius	Brazilian peppertree	Yes	Yes
Silybum marianum	milk thistle	Yes	Partial[*]
Spartium junceum	Spanish broom	Yes	Yes
Stipa tenuissima[!]	Mexican feather grass		Yes
Tamarix ramosissima[†]	tamarisk	Yes	Yes
Tragopogon sp.	salsify	Yes	
Ulmus parvifolia[!]	Chinese elm		Yes
Washingtonia robusta[‡]	Mexican fan palm	Yes	Yes

[¥]Not in original list

[*]Surveys were incomplete either due to abundance or planted nature of species

™Considered too difficult to identify in survey

[+]Includes *E. globulus* and *E. camaldulensis*

[!]Searched for but not found

[#]Includes *Pinus canariensis* and *Pinus halepensis*

[†]Referred to as *Tamarix sp.* in 2016/2017. Assumed to all be *T. ramosissima*

[‡]Referred to as *Washingtonia* sp. In 2011. Assumed to all be *W. robusta*

Methods

Both surveys were conducted using a lightweight turbine-helicopter with low noise signature and high maneuverability, using wildlands-trained helicopter pilots skilled at maneuvering at low altitudes and across steep terrain. Invasive plant populations were mapped real-time by 1-2 highly experienced botanical observers at an altitude of 30-100'. Surveys were conducted by flying transects that followed contours and varied in altitude depending on topography and flight obstacles (e.g., humans, horses, houses, power lines). Observers mapped using a Tablet PC equipped with ESRI GIS software, aerial imagery and project boundary layers, and pull-down menus for observation entries.

Populations were generally mapped by species as either points or polygons and were considered discrete if they occurred >100' from the next stand of the same species. Surveys were targeted to occur in late spring/early summer after annual forbs and grasses had senesced. Gross area was estimated by either radius or length x width for polygons or radius or direct estimate for points. Net area was derived using percent cover estimates.

Each survey began with a list of priority species to survey. The lists were developed collaboratively with land managers. Surveyors ultimately included more species than those originally listed based on what they saw in the field. Each survey noted the occurrence of a handful of species that were not noted in the other survey. It is not clear whether these species (e.g., acacia, agave, onionweed, edible fig, etc.) were not observed or were purposefully not mapped because they were not initially listed. Given that surveyors were highly conscientious about mapping new or unusual species, it is likely that most species not listed in one or the other survey were actually not observed in that survey.

Surveyors were able to capture supplemental information on other features as they surveyed for invasive plants. Both surveys documented mule deer. The 2016/2017 survey documented additional

raptor nests and populations of the locally endemic Tecate cypress (*Hesperocyparus forbesii*) trees. Lastly, both surveys recorded marijuana plantations. Whereas the 2011 did not document any, the 2016/2017 did record a plantation near to the Emergency Operations Center and the 241 Toll Road.

In order to draw useful conclusions from any comparison between the two surveys it is important to acknowledge the extent to which differences in invasive plant distribution data may be due to the surveying itself rather any actual changes on the ground. Although the survey approaches were similar in 2011 and 2016/17, there are subtle differences between how the surveys were conducted and the conditions during which they occurred. We outline some of these details as well as methodology for estimating labor investment below.

Timing. The 2011 survey occurred early/mid-June towards the end of an exceptionally wet rainfall year—the July 2010 to June 2011 total was 23.3" from the Tustin-Irvine Ranch Station weather station. Even in a wet year like this, by June most annuals had senesced and perennial invasive plants such as artichoke thistle and fountain grass were in full flower. The 2011 growing season also marked the fourth year following the 2017 Santiago Fire, which burned the lower half of the project area. The 2016/2017 survey occurred over the course of two years in July (2016) and August (2017), in which 2016 marked the last year of a record-breaking five-year drought (annual rainfall totaled <10"/yr for five successive years as compared to average rainfall of 12.8"). 2017 marked a moderately wetter year (15.9"). At the time of the survey, no large fires (>100 acre) had burned in the study area since 2007. Surveys during later months and drier conditions in 2016/2017 may have decreased detectability of some species and increased detectability of others.

Mapping methodology. Both surveys generally followed the same mapping approach as outlined above, however the 2011 survey primarily mapped populations as points (and associated length and width estimates to denote population size) whereas the 2016/2017 survey mapped populations as polygons and only rarely used points. All points and lines were converted to polygons based on their radius or length/width estimations. We were unable to determine whether these different mapping approaches altered area estimates substantially but note that the possibility exists. For instance, the mapped polygon for an invasive plant population is attributed entirely to the IPMU in which the polygon's centroid falls within, so a sizable population that overlaps an IPMU boundary could be associated with one IPMU in one survey and the adjacent IPMU in the other survey.

Observer bias. Even the most skilled botanical observers have their own unique perception of what they see. Although we cannot quantify differences between observers within and across surveys, they surely exist. For instance, though the 100' rule for populations was specified it was clearly (and understandably) not always followed. Population delimitation probably varied with observer, as did ability to locate and identify species and preference for mapping as point or polygon. Lastly, estimates of percent cover appeared to vary between the different surveys (see *Washingtonia* sp. below).

Species list. The species list for both surveys varied slightly both because of newly observed species that required surveying (e.g., onionweed), curiosity regarding wildland incursion of a domesticated species and its hybrid (e.g., nopal prickly pear), and acknowledgement that survey methodology was inadequate to detect a hard-to-see species (e.g., spiny emex and veldtgrass). We do not believe that differences in

species lists are a significant concern for this study and recommend that surveyors always be encouraged to note new species that are not on the list they have as well as to note absence of species that were on previous lists. The 2016/2017 survey introduced more complexity into interpretation of change by selectively mapping some species only in restoration sub-watersheds (Agua Chinon, Lower Silverado, West Loma, Bee Flat) rather than across the entire reserve. The surveys that included only a subset of areas for a given species are identified as "partial" in Table 1 (these species are removed from our analysis).

Area Covered. Whereas both surveys generally covered the same areas, some areas were excluded from one or the other survey. For instance, the 2011 survey did not include Coal Canyon, whereas the 2016/2017 omitted a large section of Irvine Regional Park and all of Peter's Canyon due to high human activity. Therefore, we only compared changes in the areas where flight lines overlapped across both surveys, assuming that all acreage covered by flight lines was surveyed. A map of surveyed area was provided with the 2016/17 data. We created a similar map for 2011 by buffering the provided flight lines by 600 feet on either side (typically flight lines were separated by 400-650 feet).

Some areas were marked in the 2016/17 effort as "areas not surveyed" because of aerial survey hazards such as horses, workers, wires, houses or freeway hazard (see Figure 4). However, the survey did map some invasive plant populations in those areas (50 versus 150 from the 2011 survey, both a small portion of the 8500 total populations) so we kept these areas in the comparison. In many cases the 2011 helicopter survey likely encountered similar hazards in these areas.

Detectability/Survey Feasibility. We removed the distribution data and labor data for species that could not be surveyed accurately by helicopter (e.g., *Brassica tournefortii*) or were not surveyed across the entire study area (e.g., *Carduus pycnocephalus* and *Silybum marianum*) from our analysis, even though treatment efforts for these species were significant.

Labor estimation. To compare the changes in invasive plant distribution derived from helicopter surveys to work performed on the ground, we used available labor data for weed treatment. Labor data were obtained by compiling GIS treatment data from 2012-2016 from IRC. Treatment data from OCP were unavailable and largely unknown. Therefore, comparisons were made over an area across which both management intensity and data availability varied. Some labor data – specifically data for *Nicotiana glauca* and *Cortaderia selloana* 2012 in the Agua Chinon sub-watershed and helicopter-based control subsequent to 2011 mapping – were lost. We used labor estimates from IRC. To derive person-hours for specific plants and IMPUs. Total field hours recorded for a given day were divided proportionally across the weed polygons treated for that day, based on net area or number of plants treated. These hours only reflect time spent treating plants in the field. They do not include oversight, office or travel time, and, due to our methodology for estimating time, probably underestimated investment in small populations that were treated together with large populations of other species. Time spent removing invasive species at sites designated for active planting (e.g., in restoration sub-watersheds) was also typically not recorded because it was considered part of restoration site preparation and maintenance. Labor estimates exclude time spent on species that were not mapped or inconsistently mapped by helicopter, even though a significant amount of time may have been invested in their control (for

instance, 2,114 person-hours on Saharan mustard, 665 person-hours on Italian thistle, and 386 person-hours on milk thistle). Lastly, some treatment data are missing, such as significant canyon control work within Agua Chinon in 2012, some control work by third-party entities (such as Santa Ana Watershed Association around Irvine Lake), control work by OC Parks in OC Parks-managed areas, and incidental control that was not recorded. Therefore, all treatment data are likely to be underestimates of actual work completed.

Cal-IPC acknowledges significant contributions by Yi-Chin Fang, GIS Manager at IRC, for assisting with compilation of data and estimation of labor hours.

Results

For our analysis, we compared total extent of 24 species that were surveyed consistently across the Central Reserve and adjacent lands by both surveys (Table 2). Survey results were clipped to the overlapping survey area as described in Methods (Figure 3).

Table 2. Invasive plant species compared across 2011 and 2016/2017 surveys.

Scientific Name	Common Name
Ailanthus altissima	tree-of-heaven
Albizia lophantha	plume acacia
Arundo donax	giant reed
Centaurea solstitialis	yellow starthistle
Cirsium vulgare	bull thistle
Conium maculatum	poison hemlock
Cortaderia selloana	pampasgrass
Cynara cardunculus	artichoke thistle
Encelia farinosa	brittlebush
Foeniculum vulgare	fennel
Gazania linearis	gazania
Glebionis coronarium	garland chrysanthemum
Lepidium latifolium	perennial pepperweed
Marrubium vulgare	horehound
Myoporum laetum	ngaio tree
Nerium oleander	oleander
Nicotiana glauca	tree tobacco
Pennisetum setaceum	crimson fountain grass
Phoenix canariensis	Canary Island date palm
Pinus sp.	pine sp.
Ricinus communis	castor bean
Schinus molle	Peruvian peppertree
Schinus terebinthifolius	Brazilian peppertree
Spartium junceum	Spanish broom
Tamarix ramosissima	tamarisk
Washingtonia robusta	Mexican fan palm

The 2011 survey covered 1,197 miles within the overlap region, whereas the 2016/2017 survey covered 2,099 miles (1.7x the survey effort). We can assume that, if anything, the survey team was more thorough in 2016/2017 and that the number of detections of populations may, as a result, be greater.

Reserve-wide Trends

The 2011 survey recorded a gross area of 4,956,016 m^2 (1,224 acres) for target species, which increased to 5,575,488 m^2 (1,377 acres) in 2016/2017, an increase of 12% (Table 3). Gross area is equal to polygon area mapped, and includes gaps between plants. In contrast, net area (calculated using the percent cover reported for each polygon) decreased from 772,658 m^2 (191 net acres) in 2011 to 406,593 m^2 (100 net acres) in 2016/2017, a decrease of 47% across all target species. The number of populations observed increased from 3,058 to 3,613 (an increase of 18%). Net acreage decreases may be a reflection of effective invasive plant management. Gross acreage may increase during invasive plant management because populations were more sparsely distributed and more difficult to find, especially if they extend beyond the original perimeter of a population. The increase in number of populations observed (and alternatively also the gross area reported) may be the result of rapid expansion of a few species (*Nicotiana glauca, Pennisetum setaceum, Tamarix ramosissima*) that overshadowed significant reductions in other target species (*Cynara cardunculus, Spartium junceum*).

Table 3. Gross, net area estimates and number of populations detected in 2011 and 2016/2017.

Species	Cal-IPC Rating	2011 Gross Area (m^2)	2011 Net Area (m^2)	2011 No. Pops	2016-17 Gross Area (m^2)	2016-17 Net Area (m^2)	2016-17 No. Pops	CHANGE Gross Area (m^2)	CHANGE Net Area (m^2)	CHANGE No. Pops
Ailanthus altissima ---	Moderate	8059	3063	2	1127	366	1	-6932	-2697	-1
Centaurea solstitialis	*High*	2665	2080	2	611	5	3	-2054	-2075	1
Glebionis coronaria ---	*Limited*	929	28	3	0	0	0	-929	-28	-3
Gazania linearis	*Moderate*	1172	323	5	10006	303	4	8834	-20	-1
Nerium oleander	*Unrated*	4169	1594	6	187	172	6	-3982	-1421	0
Schinus terebinthifolius ---	*Moderate*	312	212	6	5	4	1	-307	-208	-5
Lepidium latifolium	*High*	3244	2611	8	36259	8929	4	33015	6318	-4
Phoenix canariensis	*Limited*	2287	1766	9	853	610	10	-1435	-1155	1
Cirsium vulgare	*Moderate*	10093	1371	18	42191	7187	12	32098	5815	-6
Pinus sp.`	*Unrated*	7661	6964	30	11621	4609	34	3960	-2355	4
Conium maculatum ---	*Moderate*	104797	66123	31	986	148	2	-103811	-65975	-29
Schinus molle +++	*Limited*	4272	3233	32	22988	5606	62	18715	2373	30
Washingtonia robusta	*Moderate*	599	570	35	60	37	52	-539	-533	17
Arundo donax +++	*High*	1911	1427	52	104061	4395	74	102150	2968	22
Ricinus communis +++	*Limited*	64013	11514	56	430399	13167	84	366386	1652	28
Spartium junceum ---	*High*	48127	9831	64	25528	190	18	-22599	-9641	-46
Cortaderia selloana ---	*High*	55347	14560	65	55036	8443	52	-312	-6117	-13
Pennisetum setaceum +++	*Moderate*	22858	6370	75	574608	57880	227	551751	51510	152
Tamarix ramosissima +++	*High*	17568	10029	80	337251	46199	127	319683	36169	47
Encelia farinosa +++	*Unrated*	131714	27408	99	627028	84356	107	495314	56949	8
Foeniculum vulgare	*Moderate*	940591	60327	314	466947	12708	385	-473644	-47619	71
Marrubium vulgare	*Limited*	566160	99448	450	1066245	42380	597	500085	-57067	147
Nicotiana glauca	*Moderate*	832670	150171	806	943031	87815	1256	110361	-62356	450
Cynara cardunculus ---	*Moderate*	2124797	291635	810	818464	21086	495	-1306333	-270549	-315
TOTAL		4956016	772658	3058	5575488	406593	3613	619472	-366065	555

---Species that decreased in gross area, net area, and number of populations.

+++Species that increased in gross area, net area, and number of populations.

Arundo donax, Encelia farinosa, Pennisetum setaceum, Ricinus communis, Schinus molle, and *Tamarix ramosissima* increased regardless of which metric (gross area, net area, or number of populations) was used to track change. These species are clearly increasing in their overall distribution across the study area (though at a local scale they may be in decline as a result of management or other factors). Species and IPMU-specific trends are described in greater detail in the following sections.

Ailanthus altissima, Conium maculatum, Cortaderia selloana, Cynara cardunculus, Glebionis coronaria, Schinus terebinthifolius, and *Spartium junceum* declined across all three population size metrics (gross area, net area, and number of populations). These species are clearly decreasing in their overall distribution across the study area, though they may be increasing more locally in a few cases because of lack of management or other factors. See sections below for a more detailed description of trends.

The overall ranking of mapped species changed slightly. The top three most abundant species in 2011 were, based on net area and in order of decreasing cover, *Cynara cardunculus, Nicotiana glauca,* and *Marrubium vulgare*. In contrast, the three most abundant species in 2016/2017 were *Nicotiana, Encelia farinosa,* and *Pennisetum setaceum*. Changes in rankings clearly show both the effectiveness of targeted control of *Cynara cardunculus* and the relatively unchecked expansion of *Pennisetum setaceum* over five years between surveys.

Analysis of Invasive Plant Management and Plant Population Trends

Based on survey results and statewide Cal-IPC invasive plant rankings, the 2011 helicopter survey report recommended that control efforts be broadened from only a handful of highly common species, such as *Carduus pycnocephalus, Cynara cardunculus, Nicotiana glauca*, and *Silybum marianum* to include less common, incipient species (Knapp 2011). As a result, particular effort was invested into adding the control of *Ailanthus altissima, Arundo donax, Centaurea solstitialis, Pennisetum setaceum,* and *Spartium junceum*, among other species. The report also recommended that control efforts of more common species (e.g., *Cynara cardunculus*) be focused on high value habitats with isolated stands and investment areas. Invasive species removal priorities for mitigation restoration sub-watersheds were set, in part, prior to receiving survey recommendations and included species that were considered to put revegetation efforts and persistence of native habitat at risk. They are shown below (Table 4) and may explain why some species received significant control effort in one management unit and not another.

Table 4. Invasive plant species targeted for 90% removal to meet success criteria within restoration sub-watersheds.

	Restoration Sub-watershed (IPMU)			
	Agua Chinon (Limestone Canyon)	**Bee Flat Canyon** (Limestone Canyon)	**Lower Silverado Canyon** (Silverado Canyon)	**West Loma Ridge** (West Loma/Peters Canyon)
Arundo donax	(not present)	(not present)	Targeted	Targeted
Carduus pycnocephalus	Targeted	Targeted		
Cirsium vulgare	Targeted	Targeted		Targeted
Conium maculatum				Targeted
Cortadaria selloana	Targeted	(not present)		Targeted
Cynara cardunculus	Targeted	Targeted	Targeted	Targeted
Dalairea odorata	(not present)	(not present)	Targeted	
Eucalyptus spp.	(not present)		Targeted	
Foeniculum vulgare			Targeted	Targeted
Lepidium latifolium	(not present)	(not present)	Targeted	(not present)
Marrubium vulgare	Targeted			
Nicotiana glauca	Targeted	Targeted	Targeted	Targeted
Pennisetum setaceum				Targeted
Pinus spp.			Targeted	
Ricinus communis	Targeted	Targeted	Targeted	Targeted
Silybum marianum	Targeted	Targeted		
Spartium junceum	(not present)	(not present)	Targeted	Targeted
Tamarix ramosissima	Targeted	(not present)	Targeted	Targeted
Washingtonia robusta	Targeted			

IRC's work effort varied widely by IPMU as shown in Table 5 below, and depended on a prioritization of high value and core reserve areas as well as restoration subwatersheds. In all, 6036 contractor, volunteer and staff hours were recorded for direct invasive plant control in the field (1207 hrs/year during 2012-2016). As mentioned in the Methods, labor hours expended by OC Parks are unknown and would be largely focused within the Weir/Blind Canyon and Whiting Ranch IPMUs.

Table 5. IRC investment in each IPMU for species surveyed reserve-wide in 2011 and 2016/2017.

IPMU	**Person-Hours**
Agua Chinon / Loma Ridge	1,436
Black Star Canyon	679
Fremont Canyon	364
Gypsum Canyon	287
Limestone Canyon	1,488
Santiago Creek	431
Silverado Canyon	454
Weir / Blind Canyon	522
West Loma Ridge / Peters Canyon	340
Whiting Ranch	34
TOTAL	**6,036**

Focusing on the instances in which IRC invested 50 person-hours or more on a species in an IPMU, 79% substantially reduced the amount of the targeted species in that IPMU (Table 6). Collectively, the person-hours invested in these successful efforts by IRC was associated with a reduction of 161 net acres of these species. Other significant changes are described further in species and IPMU summaries.

Table 6. Top IRC investments and corresponding change in net area from survey comparison. Notable increases are highlighted.

Investment (pers-hrs)	**Invasive Plant Management Unit**	**Species**	**Change in Net Area** (m^2)	**Change** (%)
739.6	Limestone Canyon	*Cynara cardunculus*	-49,486	-84%
579.7	Agua Chinon / Loma Ridge	*Ricinus communis*	-2,494	-80%
438.6	Limestone Canyon	*Foeniculum vulgare*	-34,764	-88%
404.1	Agua Chinon / Loma Ridge	*Nicotiana glauca*	-27,805	-76%
325.5	Agua Chinon / Loma Ridge	*Cynara cardunculus*	-3,429	-96%
276.2	Fremont Canyon	*Nicotiana glauca*	628	79%
265.3	Gypsum Canyon	*Centaurea solstitialis*	-2,077	-100%
227.5	Weir/Blind Canyon	*Cynara cardunculus*	-46,134	-96%
168.2	Weir/Blind Canyon	*Nicotiana glauca*	-6,523	-71%
162.6	Santiago Creek	*Spartium junceum*	-7,096	-98%
162.0	West Loma Ridge/Peters Canyon	*Cynara cardunculus*	-28,082	-89%
156.3	Black Star Canyon	*Spartium junceum*	-2,548	-99%
144.8	Limestone Canyon	*Nicotiana glauca*	-1,278	-59%
137.0	Limestone Canyon	*Marrubium vulgare*	-10,630	-56%
129.3	Black Star Canyon	*Nicotiana glauca*	46,449	3671%
128.9	Santiago Creek	*Foeniculum vulgare*	-1,228	-71%
125.9	Black Star Canyon	*Cynara cardunculus*	-48,584	-93%
111.3	West Loma Ridge/Peters Canyon	*Foeniculum vulgare*	-6,105	-63%
96.6	Silverado Canyon	*Ricinus communis*	-3	-11%
92.6	Silverado Canyon	*Lepidium latifolium*	-190	-100%
89.1	Black Star Canyon	*Foeniculum vulgare*	-2,759	-74%
88.2	Silverado Canyon	*Spartium junceum*	2	17%
83.2	Silverado Canyon	*Foeniculum vulgare*	-1,250	-89%
78.4	Black Star Canyon	*Arundo donax*	1108	778%
72.4	Santiago Creek	*Tamarix ramosissima*	236	88%
66.3	Weir/Blind Canyon	*Ricinus communis*	6,069	126%
62.7	Agua Chinon / Loma Ridge	*Tamarix ramosissima*	-2,385	-67%
58.1	West Loma Ridge/Peters Canyon	*Nicotiana glauca*	-25,747	-75%

When labor investment was compared directly with all IPMUs combined, investment appeared related to substantial reductions in net area of the relatively abundant species *Cynara cardunculus, Nicotiana glauca, Foeniculum vulgare,* and *Spartium junceum* (Figure 5). Substantial investment in *Ricinus communis* control did not appear to affect its reserve-wide cover and likely was compromised by the species' expansion in other areas where it was not controlled (see species and IPMU-specific discussion below). Similarly, other labor investments into species that increased in net areas may have resulted in local reductions that did not translate into reserve-wide reductions in cover. Substantial labor investment into *Centaurea solstitialis* produced little change in acreage because net cover was low to begin with.

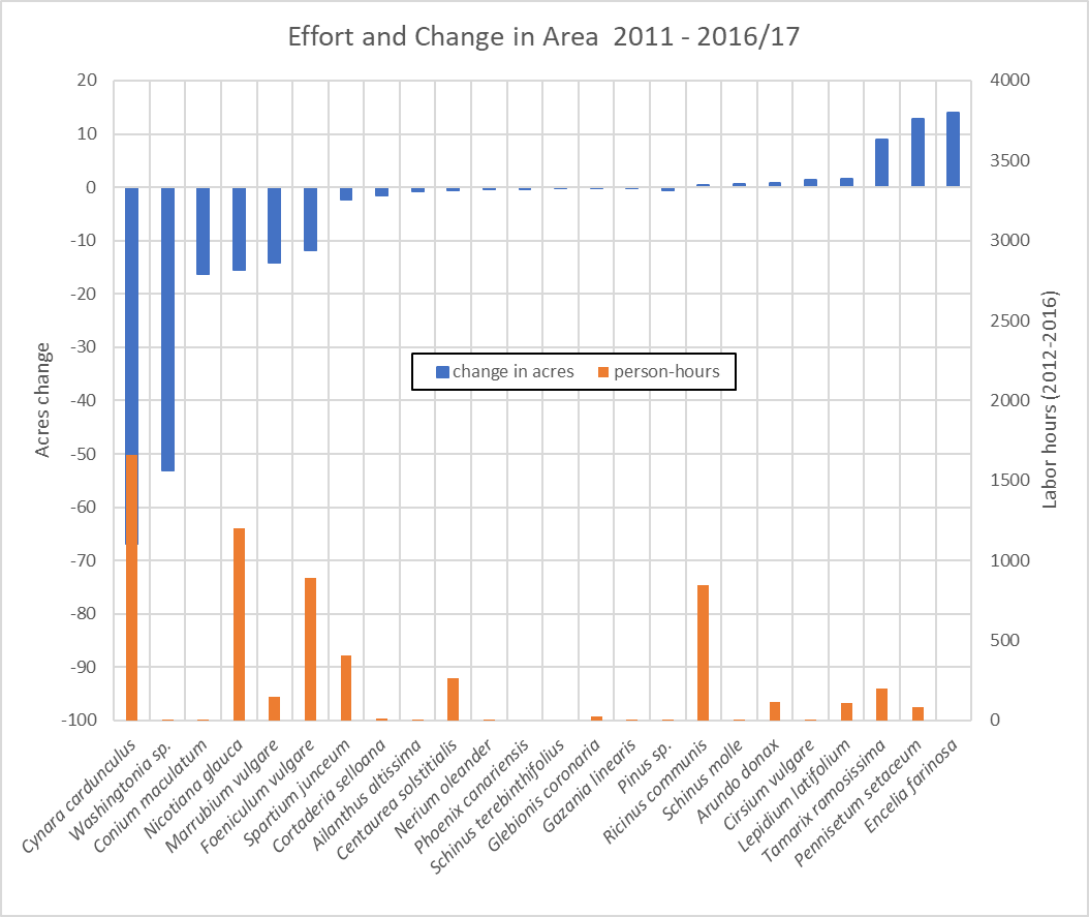

Figure 5. Effort and change in net area from 2011 to 2016/17 for plant species mapped by both surveys.

The relationship between labor investment and percent change in cover was less clear; the lack of a relationship was likely due to the substantial range in net acreage across the species being compared (Figure 6). None-the-less, the relative success of comparatively low investment on proportionally large reductions in net cover is obvious: low to moderate effort invested into *Centaurea solstitialis*, *Glebionis coronaria*, *Spartium junceum* and *Ailanthus altissima* has nearly eradicated these species, based on available data. In contrast, a nearly fourfold greater investment into *Cynara cardunculus* and threefold greater investment into *Foeniculum vulgare* than into *Spartium junceum* has produced a less dramatic effect on net cover of these species.

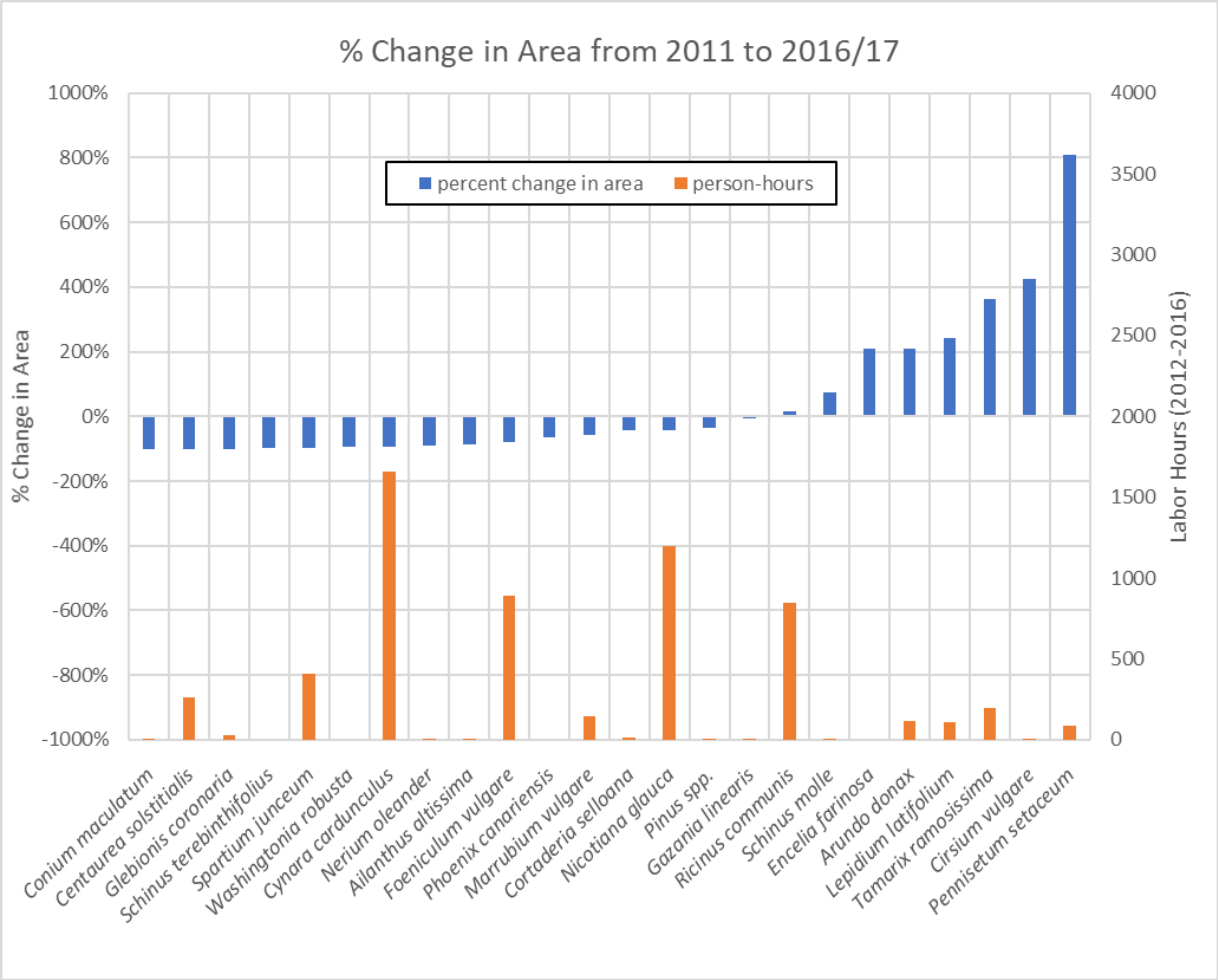

Figure 6. Effort and percent change in net area from 2011 to 2016/17 for plant species mapped by both surveys.

Although most of the efforts correlate with reductions in the targeted invasive plant, several of the species increased dramatically in IPMUs that had significant management effort. There are two main reasons this might occur. On the ground, it is possible that the effort was aimed at only a small portion of the populations of the target plant in a given IPMU, perhaps to protect an investment area (e.g., restoration sub-watershed or past stewardship investment) or because multiple ownerships or management approaches co-occurred within a single IPMU (e.g., Weir/Blind Canyon and Black Star Canyon). Secondly, in the helicopter mapping, some widespread species were mapped with very large polygons in 2016/2017, and the area of such a polygons is attributed to whichever IPMU its centroid falls within, potentially giving an artificially low estimate of area in one IPMU and an artificially high estimate in the neighboring IPMU.

With the caveat that labor estimates are approximate and incomplete, it is still instructive to examine the amount of reduction in invasive plant area per amount of investment in control. It should be noted that many things affect these estimates:

- IRC may not manage the entire IPMU, so a plant being controlled by IRC in part of the IPMU could be spreading in another part of the IPMU.
- Smaller plants have many more individuals per area and may take more time to remove than has been documented.
- Some species (e.g., *Centaurea solstitialis*) require multiple visits annually to the same place to reduce area while others do not.
- As managers approach eradication small decreases in percentage typically require more effort than initial reductions since the same area IPMUs be surveyed for any remaining plants.

Detailed Results by Species

The following tables show the area of the given invasive plant species by IPMU from the 2011 and 2016-17 surveys. Areas are in square meters, and shown in italics when the area increased. Person-hours invested are by IRC from 2012-2016. Notes are added to highlight regions and conditions under which species appear to be increasing in cover but are generally not added where they have been decreasing.

***Ailanthus altissima* (tree-of-heaven)**

	2011	2016-17	Change	Per-hrs
Limestone Canyon	1	0	-100%	5
Weir / Blind Canyon	3,062	366	-88%	
	3,063	366	-88%	5

Tree-of-heaven was targeted for control. This species requires multiple return visits for treatment and years of surveillance before it can be considered locally eradicated. Small stands were controlled in Gypsum Canyon, Santiago Canyon and Silverado Canyon IPMUs but were not observed by either helicopter survey.

- Limestone Canyon: The population in Limestone Canyon was treated multiple times and should now be on surveillance.
- Weir/Blind Canyon: The dramatic reduction in cover represented change in a single population and is either due to changes in area estimation, control work by OC Parks that was not reported, or local decline of the species. The population occurs in Irvine Regional Park.

***Arundo donax* (giant reed)**

	2011	2016-17	Change	Per-hrs
Black Star Canyon	*142*	*1,250*	*+778%*	78
Limestone Canyon	651	9	-99%	see below
Santiago Creek	587	21	-96%	16
Silverado Canyon	14	0	-99%	28
Weir / Blind Canyon	*33*	*3,017*	*+9,075%*	<1
West Loma Ridge / Peters Canyon	0	97	++	
	1,427	*4,395*	*+208%*	114

Giant reed was targeted for control by IRC. It was also treated around the Irvine Lake perimeter by the Santa Ana Watershed Authority (labor investment and treatment data are only partially reported) which explains the observed reduction in Limestone Canyon. An isolated stand was also controlled in Fremont Canyon but not observed by helicopter.

- Black Star Canyon: The increase is partially attributable to increases in *Arundo* cover upstream of Irvine Lake in an area that is reserved for future mitigation by a third party and could not be treated. Other acreage was apparently missed during control efforts.
- Weir/Blind Canyon: the increase in the IPMU appears to reflect significant expansion of Arundo in Santiago Oaks and Irvine Regional Park.

***Centaurea solstitialis* (yellow starthistle)**

	2011	2016-17	Change	Per-hrs
Gypsum Canyon	2,080	3	-100%	265
Weir / Blind Canyon	*0*	*2*	*++*	
	2,080	5	-100%	265

Yellow starthistle was targeted for control by IRC. Significant additional acreage was found in 2014 along the CalTrans right-of-way along the 241 Tollroad. This area was excluded from the mapping effort.

- Gypsum Canyon: As a result of control efforts targeting the population found by helicopter in 2011, the population significantly declined, leaving only remnant stands along its boundary.
- Weir/Blind Canyon: This new observation is immediately adjacent to the population occurring along the 241 Tollroad and threatens to encroach further if not treated.

***Cirsium vulgare* (bull thistle)**

	2011	2016-17	Change	Per-hrs
Agua Chinon / Loma Ridge	37	0	-99%	
Black Star Canyon	*3*	*1,592*	*+55,195%*	2
Limestone Canyon	298	0	-100%	
Santiago Creek	1,030	131	-87%	
Silverado Canyon	3	0	-100%	<1
Weir / Blind Canyon	*5*	*461*	*+9,120%*	
	1,371	*7,187*	*+424%*	2

Bull thistle was prioritized by IRC for control specifically in restoration sub-watersheds and was treated as found otherwise. Its control may have been under-recorded when other, more common, thistles were being treated concurrently .

- Black Star Canyon: The dramatic increase of bull thistle in Black Star Canyon occurred within an area that has been reserved for future mitigation by a third party and could not be treated.
- Weir/Blind Canyon: Populations that appeared and/or grew occurred in Santiago and Irvine Regional Park.

***Conium maculatum* (poison hemlock)**

	2011	2016-17	Change	Per-hrs
Agua Chinon / Loma Ridge	3,577	148	-96%	
Black Star Canyon	6,918	0	-100%	6
Santiago Creek	25,521	0	-100%	
Silverado Canyon	173	0	-100%	1
Weir / Blind Canyon	29,934	0	-100%	
	66,123	148	-100%	7

Poison hemlock was only prioritized for control in one restoration sub-watershed in West Loma / Peters Canyon. Its cover decreased dramatically between 2011 and 2016/2017. Decreases were probably not the result of the effort invested into its control but may rather reflect the species' decline during the prolonged drought between 2011 and 2016. Alternatively, later season survey conditions in 2016/2017 could have reduced detectability. Reductions in Weir/Blind Canyon may reflect unreported control efforts by OC Parks in Santiago Oaks and Irvine Regional Park but are more likely to have been due to the unknown factors associated with its decline in other regions.

***Cortaderia selloana* (pampasgrass)**

	2011	2016-17	Change	Per-hrs
Agua Chinon /				
Loma Ridge	561	72	-87%	7
Black Star Canyon	42	5	-87%	
Fremont Canyon	8	2	-72%	2
Gypsum Canyon	*16*	*20*	*+26%*	
Limestone Canyon	22	9	-61%	
Santiago Creek	4		-100%	
Weir / Blind Canyon	*130*	*549*	*+323%*	
West Loma Ridge / Peters Canyon	13,728	7,479	-46%	
Whiting Ranch	*49*	*307*	*+531%*	4
	14,560	8,443	-42%	11

Pampasgrass was prioritized for control by IRC. Remote locations of the species were treated by helicopter (2011-2014), when possible, and control efforts were limited in remote areas when they were not facilitated by helicopter. Control effort is likely underestimated for this species because helicopter control data for 2011 and ground efforts in Agua Chinon in 2012 are missing. Stands occurring in restoration sub-watersheds were consistently surveyed and removed, though labor hours do not appear to reflect work performed. Whiting Ranch, Weir/Blind Canyon, Black Star, and Gypsum Canyon were not treated beyond remote helicopter-mediated control (to the best of our knowledge).

Declines appear to be the result of (1) differences in mapping protocol (or plant condition) similar to that observed for Canary Island palm (see below) as well of (2) successful control effort. Isolated plants were typically mapped as $9m^2$ net area in 2011, whereas they were mapped as $0.7m^2$-$7m^2$ net area in 2016/2017. Nonetheless, some larger patches actually increased in size and there were overall changes in number of populations (isolated patches) that appeared to reflect successful control effort (see below). For instance, the number of populations in Agua Chinon/Loma Ridge decreased from 10 to 3 but increased in Whiting Ranch from 4 to 10.

- Gypsum Canyon: Populations were not treated and net area increased. A new population was observed west of the Toll Road.
- Weir Canyon/Blind: Increases occurred in Santiago and Irvine Regional Park.
- Whiting Ranch: Increases occurred via new populations along the perimeter of Whiting Ranch.

***Cynara cardunculus* (artichoke thistle)**

	2011	2016-17	Change	Per-hrs
Agua Chinon / Loma Ridge	56,802	1,170	-98%	326
Black Star Canyon	52,166	3,582	-93%	126
Fremont Canyon	8,997	97	-99%	41
Gypsum Canyon	112	74	-34%	
Limestone Canyon	58,614	9,128	-84%	740
Santiago Creek	15	7	-54%	
Silverado Canyon	2	0	-100%	6
Weir / Blind Canyon	47,858	1,724	-96%	228
West Loma Ridge / Peters Canyon	31,729	3,647	-89%	162
Whiting Ranch	35,340	1,658	-95%	27
	291,635	21,086	-93%	1660

Artichoke thistle was prioritized for control, with special attention placed on IRC-managed sections of Limestone Canyon, Agua Chinon/Loma Ridge, Weir/Blind Canyon, and West Loma Ridge/Peters Canyon . It was not controlled in Gypsum Canyon. Overall declines in artichoke thistle are probably both a result of successful control and of dry conditions in the interim period. The 2016/2017 survey showed not only a decrease in net area, but also an encouraging retraction in the distribution of isolated stands of the species. See Figure 7.

- Limestone Canyon: Decreases in cover are dampened by inclusion of a large area (East Orange II) that was not under IRC management or otherwise being managed for invasive plants.
- Whiting Ranch: Decreases may reflect helicopter-assisted control (23 hours dedicated) and other OC Parks control work that was not documented.

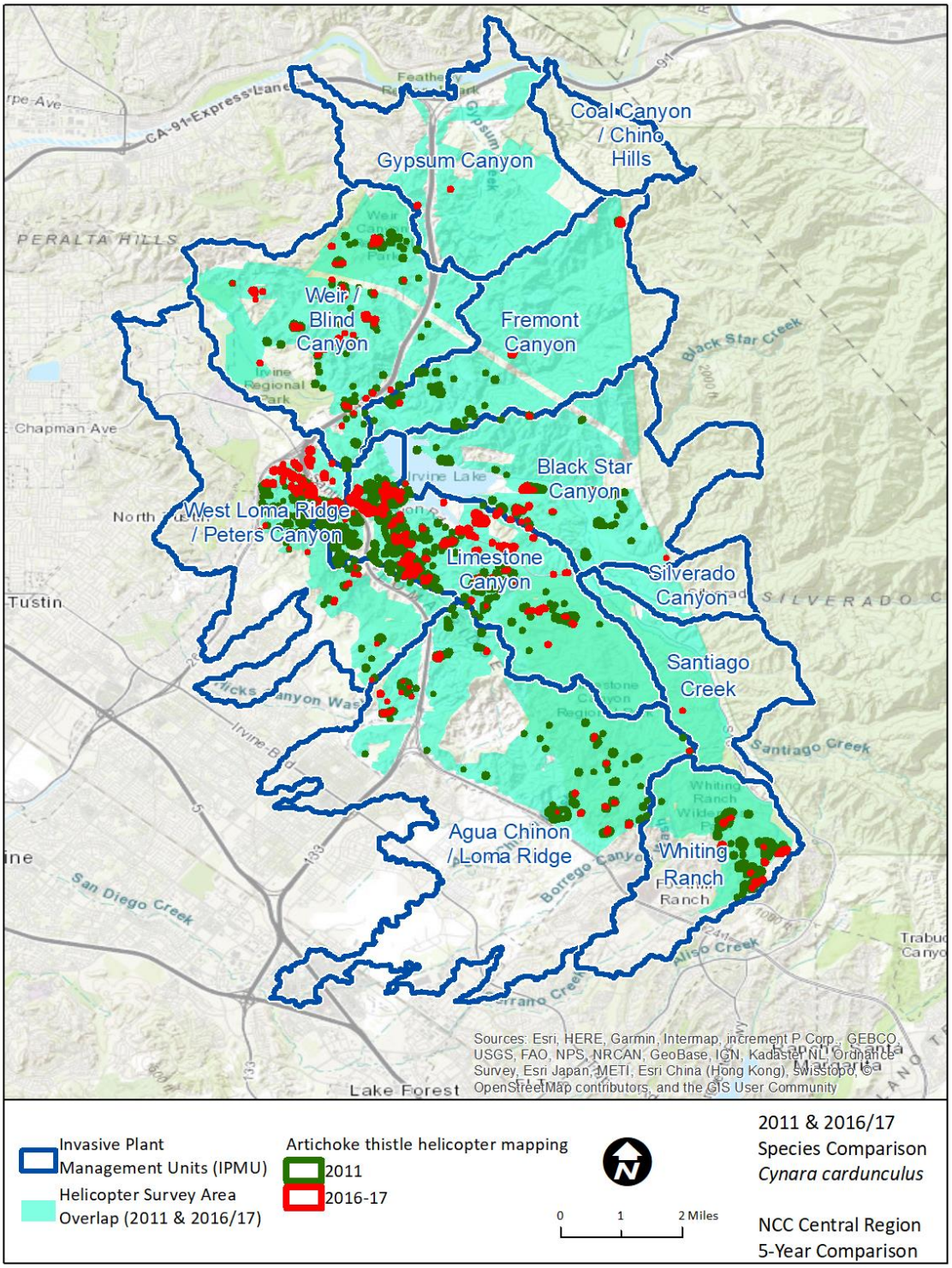

Figure 7. Decreased distribution of artichoke thistle in 2016/2017 (red) relative to 2011 (green).

***Encelia farinosa* (brittlebush)**

	2011	2016-17	Change
Agua Chinon / Loma Ridge	*24,570*	*29,117*	*+19%*
Fremont Canyon	*0*	*530*	*++*
Gypsum Canyon	*0*	*50,996*	*++*
Limestone Canyon	*2,482*	*3,391*	*+37%*
Santiago Creek	13	11	-11%
Weir / Blind Canyon	*122*	*292*	*+139%*
West Loma Ridge / Peters Canyon	220	0	-100%
Whiting Ranch		*19*	*++*
	27,408	*84,356*	*+208%*

Brittlebush was not prioritized for control. This species increased in nearly all IPMUs. It is native to other (drier) regions of California and was seeded in early roadside revegetation and restoration projects. Brittlebush hybridizes readily with locally native *Encelia californica*. Surveyed plants consist of hybrid swarms that still carry the characteristic gray leaves of *E. farinosa*. This species has not been controlled and its expansion across nearly all IP IPMUs is intriguing in light of uncharacteristically dry conditions between 2011 and 2016. The ecological impacts of the spread of *E. farinosa* and its hybrid derivatives are as yet unknown.

- Agua Chinon: Increases were the result both of expansion of existing populations and new populations that were discovered.
- Fremont Canyon: One new population was mapped at the base of Fremont Canyon near the outflow of Irvine Lake.
- Gypsum Canyon: A large population was mapped in 2016/2017 that spanned an area not entirely mapped in 2011. Either this population has emerged since 2011 or it was missed in 2011.
- Weir/Blind Canyon: New populations and expansions of existing populations were found.
- West Loma/Peters Canyon: One population mapped in 2011 was not recorded in 2016/2017. Either it disappeared or was missed.
- Whiting Ranch: Two populations were mapped in 2016/2017 that were missed in 2011. They occurred along the perimeter of the 2011 survey area.

***Foeniculum vulgare* (fennel)**

	2011	2016-17	Change	Per-hrs
Agua Chinon / Loma Ridge	*218*	*1,110*	*409%*	4.2
Black Star Canyon	3,739	980	-74%	89
Fremont Canyon	*10*	*492*	*4633%*	16
Gypsum Canyon	269	76	-72%	5
Limestone Canyon	39,377	4,613	-88%	439
Santiago Creek	1,729	502	-71%	129
Silverado Canyon	1,409	159	-89%	83
Weir / Blind Canyon	3,885	898	-77%	14
West Loma Ridge / Peters Canyon	9,628	3,522	-63%	111
Whiting Ranch	*61*	*356*	*480%*	
	60,327	12,708	-79%	891

Fennel was prioritized for control in restoration sub-watersheds and Limestone Canyon, but only controlled incidentally in other areas during artichoke thistle control. Attempts were made to record control efforts separately from artichoke thistle, but labor hours listed are probably still underestimates. Notably, fennel generally declined in IPMUs where it was controlled and increased in those areas where it was not.

- Agua Chinon/Loma Ridge: Fennel has expanded along edge habitat where it has not been controlled. Future treatment plans may consider targeted isolated populations to prevent further spread.
- Fremont Canyon: Fennel has expanded significantly within the Santiago Creek region of this IPMU where it had not been treated.
- Whiting Ranch: Fennel has expanded along the eastern edge of Whiting Ranch where it had originally been recorded in 2011.

***Gazania linearis* (gazania)**

	2011	2016-17	Change	Per-hrs
Gypsum Canyon	*0*	*262*	*++*	*<1*
Santiago Creek	323	42	-87%	2.8
	323	*304*	*-5%*	2.8

Gazania was not prioritized for control but was controlled opportunistically when encountered.

***Glebionis coronaria* (garland chrysanthemum)**

	2011	2016-17	Change	Per-hrs
Agua Chinon / Loma Ridge	28	0	-100%	25
	28	*0*	*-100%*	25

Garland chrysanthemum was prioritized for control by IRC. Based on surveys and subsequent control reports, control efforts appear to have eradicated the single population that was recorded in 2011. The population should now be on an annual surveillance program.

***Lepidium latifolium* (perennial pepperweed)**

	2011	2016-17	Change	Per-hrs
Black Star Canyon	73	*6349*	*+8728%*	13
Limestone Canyon	0	37	++	
Santiago Creek	2129	0	-100%	5
Silverado Canyon	190	0	-100%	93
Weir / Blind Canyon	*219*	*2543*	*+1061%*	
				111

Perennial pepperweed was prioritized for control by IRC within restoration sub-watersheds and accessible portions of Santiago Creek. Additional control was conducted in Gypsum Canyon beyond the survey comparison perimeter. There is significant expansion in Black Star and Weir/Blind Canyons.

***Marrubium vulgare* (horehound)**

	2011	2016-17	Change	Per-hrs
Agua Chinon / Loma Ridge	5,282	5,550	+5%	8
Black Star Canyon	*227*	*271*	*+19%*	<1
Coal Canyon / Chino Hills	2	0	-100%	
Fremont Canyon	4,161	1,033	-75%	
Gypsum Canyon	471	52	-89%	
Limestone Canyon	18,874	8,244	-56%	137
Santiago Creek	*109*	*463*	*+325%*	<1
Silverado Canyon	*15*	*21*	*+43%*	
Weir / Blind Canyon	*299*	*511*	*+71%*	
West Loma Ridge / Peters Canyon	4,159	1,031	-75%	1
Whiting Ranch	65,848	25,205	-62%	
	99,448	42,380	-57%	147

Horehound was only prioritized for control in a subset of restoration sub-watersheds and otherwise only treated incidentally. Although it has decreased in net area, it appears to have expanded its distribution

across the study area. Decreases in net area within some IPMUs that did not receive control cannot be explained by management actions, leaving only drought and survey methodology (i.e., estimations of net area) as potential explanations.

- Santiago Creek: Increases were due mostly to expansion of a single colony along the border of the IRC-managed reserve area.
- Silverado Canyon: Increases occurred primarily from a previously mapped stand adjacent to old helicopter landing pad by the Baker Canyon loop trail.
- Weir/Blind Canyon: Increases occurred primarily from new stands observed within Weir Canyon.

***Nerium oleander* (oleander)**

	2011	2016-17	Change	Per-hrs
Agua Chinon / Loma Ridge	*0*	*2*	*++*	
Black Star Canyon	*2*	*46*	*+1,860%*	2
Gypsum Canyon	1,579	0	-100%	
Santiago Creek	6	2	-73%	
Silverado Canyon	7	2	-75%	2
West Loma Ridge / Peters Canyon	*0*	*121*	*++*	
	1,594	172	-89%	4

Oleander was not prioritized for control but was controlled incidentally. An additional isolated stand of this species was controlled in Fremont Canyon but not observed by helicopter. The dramatic drop in net area in Gypsum Canyon is the result of a single stand observed in 2011 not being reported in 2016/2017. It is unlikely to have disappeared on its own; it was most likely either mis-identified in 2011 or missed in 2016/2017 and should therefore be ground-truthed.

- Agua Chinon/Loma Ridge: One new stand was observed along the reserve boundary, adjacent to a wood lot (Area R).
- Black Star Canyon: One new stand was observed near Irvine Lake.
- West Loma Ridge/Peters Canyon: On new stand was observed in the East Orange I OC Parks Easement.

***Nicotania glauca* (tree tobacco)**

	2011	2016-17	Change	Per-hrs
Agua Chinon / Loma Ridge	36,550	8,745	-76%	404
Black Star Canyon	*1,265*	*47,714*	*+3,671%*	129
Fremont Canyon	*794*	*1,423*	*+79%*	276
Gypsum Canyon	33,713	4,133	-88%	3
Limestone Canyon	2,169	890	-59%	145
Santiago Creek	*278*	*2,950*	*+963%*	14
Weir / Blind Canyon	9,217	2,694	-71%	168
West Loma Ridge / Peters Canyon	34,405	8,658	-75%	58
Whiting Ranch	30,582	10,608	-65%	1
	150,171	87,815	-42%	1198

Tree tobacco was only prioritized for control in restoration sub-watersheds and volunteer stewardship projects. Decreases are likely due only in part to control efforts and increases in some IPMUs are notable. Cover decreased significantly and the distribution of tree tobacco was restricted in some locations, but number of new stands were observed in other areas (e.g., Santiago Creek, Irvine Regional Park, and Weir Canyon). Approximately 15 hours of additional control effort were invested to control this species in Silverado IPMU, where it was not recorded in either helicopter survey.

- Black Star Canyon and Santiago Creek: The large increase in tree tobacco acreage occurred both in the “stay out” upstream of Irvine Lake reserved for future mitigation as well as along the length of Santiago Creek, where it was largely not included in riparian invasive control work.
- Coal Canyon/Chino Hills: the dramatic decrease in acreage is merely a byproduct of the methodology used to assign invasive plant polygons to IPMUs. The previously mapped populations were merged into a single polygon that was associated with the adjacent Gypsum Canyon IPMU for 2016/2017.
- Fremont Canyon: Most of the increase in tree tobacco cover stems from one new large stand identified along the boundary between the Irvine Ranch Open Space and Cleveland National Forest, in a remote section of the IPMU.
- Santiago Creek: Increases were the result of new populations that were mapped within Santiago Creek. These were not prioritized for control and may have established in the wake of Spanish broom control in the same area.

***Pennisetum setaceum* (fountaingrass)**

	2011	2016-17	Change	Per-hrs
Agua Chinon / Loma Ridge	*2,900*	*11,909*	*+311%*	19
Black Star Canyon	*1*	*175*	*+14,426%*	1
Fremont Canyon	*8*	*2,007*	*+23,901%*	1
Gypsum Canyon	0	*16,797*	*++*	
Limestone Canyon	*1*	*205*	*+36,691%*	1
Santiago Creek	*844*	*4,629*	*+448%*	8
Weir / Blind Canyon	*1,777*	*20,745*	*+1,067%*	46
West Loma Ridge / Peters Canyon	*818*	*1,319*	*+61%*	8
Whiting Ranch	*19*	*94*	*+389%*	2
	6,370	*57,880*	*+809%*	86

Fountain grass was prioritized in restoration sub-watersheds and across the wider study area where possible. However, control efforts were clearly not sufficient to slow its spread. Based on helicopter surveys, this species is the most rapidly spreading perennial invasive species within the study area. Acreage changes overall reflect both new stands and expansions of existing stands. The 2016/2017 survey identifies several new isolated stands (e.g., in Limestone Canyon and Agua Chinon / Loma Ridge) that can be prioritized for removal (Figure 8).

- Weir / Blind Canyon: Fountain grass cover increases were greatest in this IPMU. New populations appeared throughout Weir and Blind Canyon and over half the new area reported was located in Santiago Regional Park.

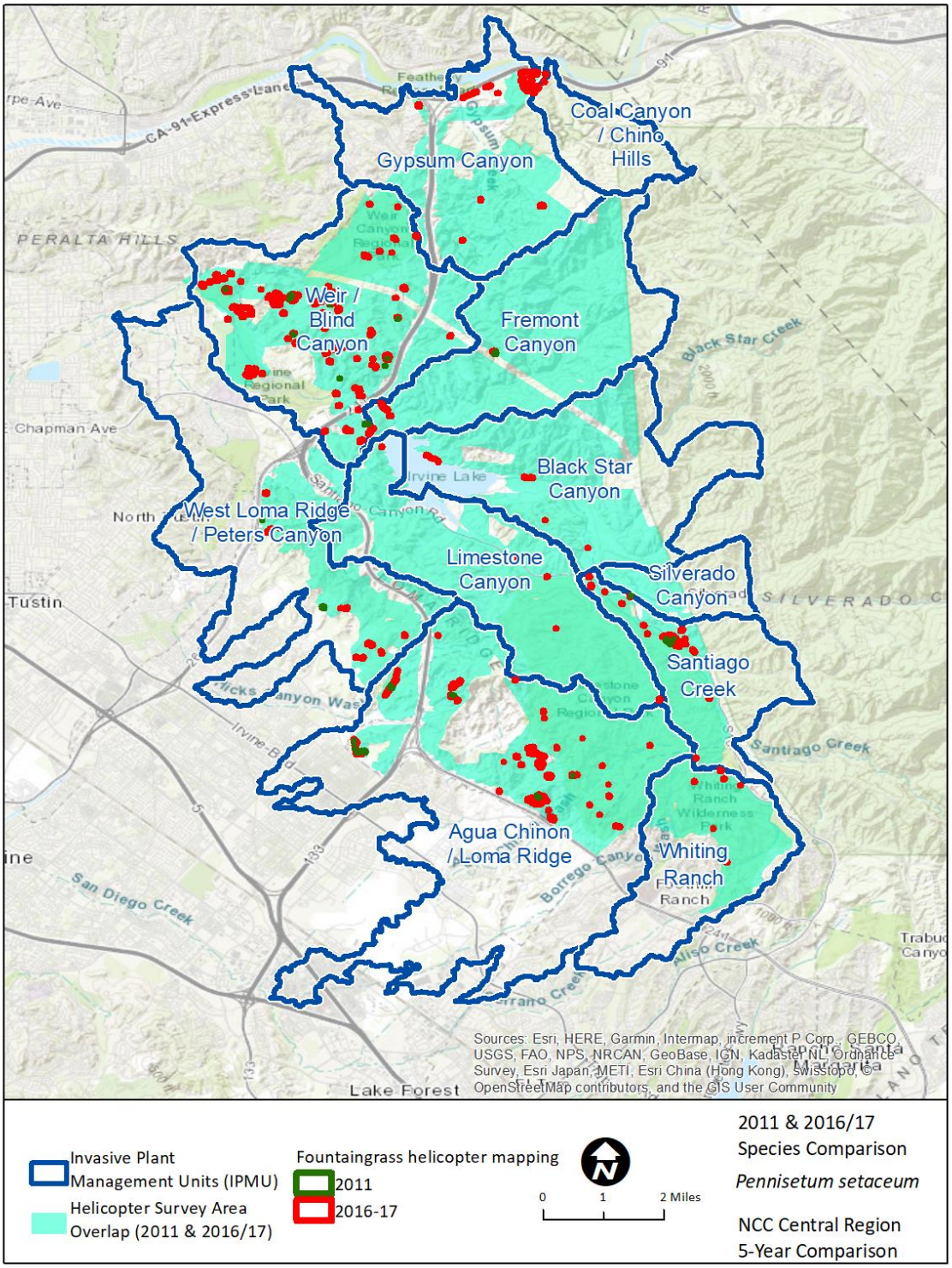

Figure 8. Increase in distribution of fountain grass in 2016/2017 (red) relative to 2011 (green).

***Phoenix canariensis* (Canary Island date palm)**

	2011	2016-17	Change
Black Star Canyon	74	18	-75%
Limestone Canyon		*7*	*++*
Weir / Blind Canyon	351	170	-52%
West Loma Ridge / Peters Canyon	1,340	415	-69%
	1,766	610	-65%

Canary Island date palm was not prioritized for control but nonetheless decreased in cover in all IPMUs but one, where a new polygon was recorded. Differences are likely a result both of mapping differences across observers and, potentially, drought conditions. In 2011, most palms were estimated to have close to 100% net cover, whereas palms mapped in 2016/2017 were all recorded to have cover of 50-75%. A single palm mapped in 2011 and 2016/2017 was estimated to have a size of 232m^2 and 49m^2, respectively .

***Pinus* spp.**

	2011	2016-17	Change	Per-hrs
Agua Chinon / Loma Ridge	2,304	-	-100%	
Black Star Canyon	2,698	1,207	-55%	
Limestone Canyon	*74*	*347*	*+367%*	
Santiago Creek	1,098	453	-59%	
Silverado Canyon	790	2	-100%	2
Weir / Blind Canyon	-	*529*	*++*	
West Loma Ridge / Peters Canyon	-	*2,071*	*++*	
	6,964	4,609	-34%	2

Pines were only prioritized for control in one sub-watershed (Lower Silverado), however they decreased dramatically in some IPMUs and increased in others. Given the overall small area and number of populations in the study area, most of the difference may be attributable to mapping area (e.g., there were populations found in 2011 that were not located in 2016/2017 and vice versa). Several stands (for instance, acreage denoted in Agua Chinon / Loma Ridge and Limestone) occurred in edge habitat and may not have been mapped consistently. Net area estimates appeared to be consistent across both surveys.

- Limestone Canyon: Increase is from two stands stand mapped in East Orange I OC Parks Easements.
- Weir/Blind Canyon: Increase is from two stands mapped in Santiago Oaks Regional Park.
- West Loma Ridge / Peters Canyon: Increase is from two stands, one along edge habitat in the East Orange I Easement and One in West Loma along the Toll Road Right-of-Way.

***Ricinus communis* (castor bean)**

	2011	2016-17	Change	per-hrs
Agua Chinon / Loma Ridge	3,102	608	-80%	580
Black Star Canyon	48	407	745%	46
Fremont Canyon	1		-100%	18
Gypsum Canyon	2,487	15	-99%	3
Limestone Canyon	77	61	-21%	16
Santiago Creek	*294*	*962*	*+228%*	*17*
Silverado Canyon	29	26	-11%	
Weir / Blind Canyon	*4,816*	*10,885*	*+126%*	*66*
West Loma Ridge / Peters Canyon	660	203	-69%	<1
	11,514	13,167	14%	843

Castor bean was prioritized across sub-watersheds and Santiago Creek. Often this species was controlled incidentally during Spanish broom control efforts. Although some IPMUs show significant reduction in acreage, others show increases. The overall net increase in acreage is surprising and may have several causes.

- Black Star Canyon: Increases represent stands that were missed during control efforts.
- Santiago Creek: Increases represent stands that were missed and may have been in roadside right-of-ways.
- Weir/Blind Canyon: Increases stem primarily from substantial growth in stands originally found in 2011 surveys in Santiago Oaks and Irvine Regional Park. Stands also increased on Irvine Ranch Open Space lands adjacent to the 241 Tollroad, along the "MWD" road.

***Schinus terebinthifolius* (Brazilian pepper tree)**

	2011	2016-17	Change
Black Star Canyon	77	4	-95%
Santiago Creek	135	0	-100%
	212	4	-98%

Brazilian peppertree was not prioritized for control yet cover decreased substantially. Differences are partly due to differences in mapping estimates (a single tree was mapped as 21m^2 in 2011 and 4m^2 in 2017/2018) as well as to either detectability or local decline. Remaining stands recorded in 2011 were not observed in 2016/2017.

***Schinus molle* (Peruvian pepper tree)**

	2011	2016-17	Change	per-hrs
Agua Chinon / Loma Ridge	151	104	-31%	
Black Star Canyon	46	0	-100%	
Fremont Canyon	*0*	*382*	*++*	
Gypsum Canyon	1,032	623	-40%	
Limestone Canyon	*473*	*881*	*+86%*	<1
Santiago Creek	1,375	1,207	-12%	<1
Silverado Canyon	119	96	-19%	<1
Weir / Blind Canyon	*37*	*476*	*+1,180%*	
West Loma Ridge / Peters Canyon	0	1,546	++	
Whiting Ranch	0	291	++	
	3,233	*5,606*	*+73%*	1

Peruvian peppertree was not prioritized for control but was controlled incidentally when encountered. Differences in cover estimates could not be attributed to a single cause and may reflect some local expansion.

- Fremont Canyon: Increases were due to new stands identified near the outflow of Irvine Lake (Serrano Water District).
- Limestone Canyon: Increases were due to new stands identified in a section of the East Orange I Easement.
- Weir/Blind Canyon: Increases cover occurred by the discovery of one new stand of the species in Santiago Oaks.
- West Loma Ridge/Peters Canyon: Increased cover was primarily from new stands identified adjacent to a building located by the 241/261 interchange. Plants may have been planted in part, but additional individuals growing apparently as volunteer in the study area suggest potential spread.
- Whiting Ranch: Increases were due to the discovery of two isolated trees within Whiting Ranch.

***Spartium junceum* (Spanish broom)**

	2011	2016-17	Change	Per-hrs
Black Star Canyon	2,568	20	-99%	156
Santiago Creek	7,248	152	-98%	163
Silverado Canyon	*15*	*17*	*+17%*	88
	9,831	190	-98%	407

Spanish broom was prioritized for control. Control was implemented across the three IPMUs where it is known to occur. Slight increases in Silverado Canyon were associated with two new stands that were identified and the persistence of another. Spanish broom was controlled (<1hr) in Limestone Canyon where it had not been observed by helicopter.

***Tamarix ramosissima* (saltcedar)**

	2011	2016-17	Change	per-hrs
Agua Chinon / Loma Ridge	3,545	1,160	-67%	63
Black Star Canyon	*563*	*24,389*	*+4,232%*	28
Fremont Canyon	*0*	*33*	*+35,526%*	8
Gypsum Canyon	*117*	*4,271*	*+3,557%*	1
Limestone Canyon	121	51	-58%	
Santiago Creek	267	503	88%	72
Silverado Canyon	29	1	-98%	23
Weir / Blind Canyon	*697*	*11,715*	*+1,581%*	
West Loma Ridge / Peters Canyon	1,403	1,250	-11%	
Whiting Ranch	3,288	2,826	-14%	1
	10,030	*46,199*	*+361%*	197

Tamarisk was prioritized for control reserve-wide and within all restoration sub-watersheds where it was recorded. However, control efforts were only partially effective and the overall cover of this species increased fourfold over the two survey periods. See Figure 9.

- Agua Chinon / Loma Ridge: Although cover decreased in this IPMU overall, two large new populations were found along edge habitat. One was directly south of the Bowerman Landfill, adjacent to an orchard. The second was along an access spur near to and north of the current native seed farm.
- Black Star Canyon: Increases were mostly due to significant increases in a previously mapped stand just upstream of Irvine Lake. This stand was located in the area reserved for future mitigation by a third party. Three other new stands were reported upstream of this site as well.
- Fremont Canyon: The increase was from a single new stand mapped in a remote section of the IPMU. Other Tamarisk were found by foot surveys and controlled, but are not documented on the helicopter survey.
- Gypsum Canyon: Increases are the result of several new populations that were mapped in a section of the IPMU that was only partially mapped in 2011. These populations overlap the new large stand of Brittlebush that was found (see above) and suggest that the region may have been missed in the 2011 surveys. Nonetheless, the populations are large and likely expanding.

- Santiago Creek: Increases were the result both of two new small stands reported as well as the expansion of previously mapped tamarisk.
- Weir/Blind Canyon: Increases were primarily from three new populations mapped within Santiago Oaks Regional Parks. An existing population at the base of Weir Canyon in an area reserved for future mitigation by a third party (and thus inaccessible for control) in addition to expansion of a population and a new occurrence along the NE section of the IP MU .
- West Loma / Peters Canyon: Increases were largely the result of increase in size of populations that were previously mapped within a remote section in the southwestern section of the IPMU.

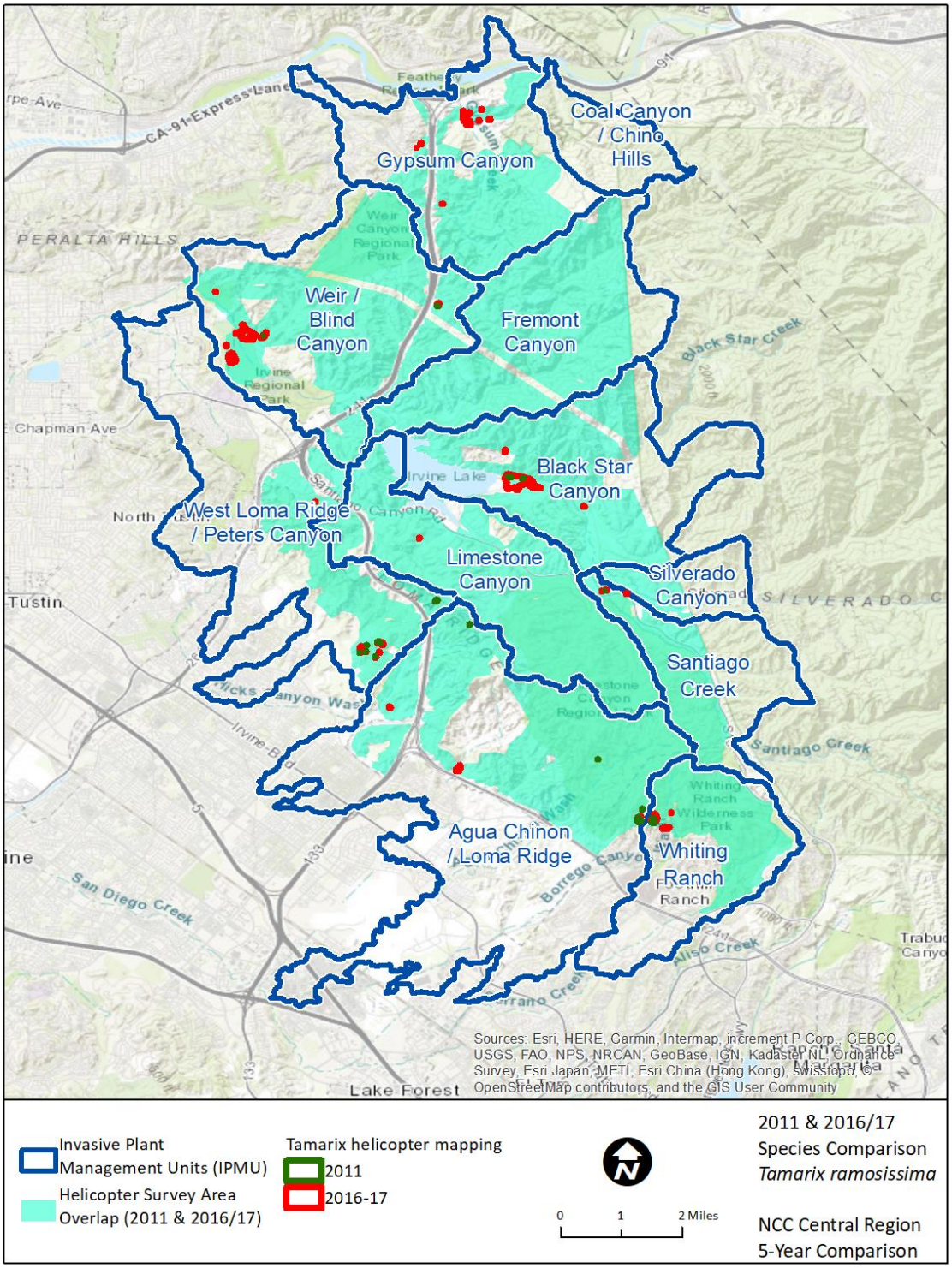

Figure 9. Increase in saltcedar distribution in 2016/2017 (red) relative to 2011 (green).

***Washingtonia (robusta)* Washingtonia**

	2011	2016-17	Change	pers-hrs
Agua Chinon / Loma Ridge	113	4	-97%	<1
Black Star Canyon	67	8	-88%	
Coal Canyon / Chino Hills				
Fremont Canyon	73	2	-97%	
Limestone Canyon	38	4	-88%	<1
Santiago Creek	46	1	-97%	<1
Weir / Blind Canyon	184	7	-96%	
West Loma Ridge / Peters Canyon	37	1	-98%	<1
Whiting Ranch	13	4	-71%	
	570	37	-93%	1

Washingtonia palm was only prioritized for control in one restoration sub-watershed and was otherwise controlled incidentally. It was found and controlled in Silverado Canyon (<1 hr investment) but not observed in either survey by helicopter. Dramatic declines appear to be largely due to differences in mapping protocol similar to that observed for Canary Island palm. Most stands mapped in 2016/2017 had been mapped previously but recorded a significantly smaller net area. Virtually all stands were individual trees, which were each mapped at a net area of 0.73m^2, whereas isolated trees were typically mapped as 9m^2. Therefore, we can presume that there was no actual net change in *Washingtonia* cover over the study period.

Results by Management Unit

Acreage change, labor effort (total hours invested between 2012-2016), and an index of severity of increase are presented below by IPMU. Increases >50% and <100% were scored as a moderate increase (↑); increases >100% and <1000% were scored as a high increase (↑↑); and increases >1000% were scored as exceptional increase (↑↑↑). Increases relative to none observed in 2011 are also scored with arrows when they appear notable. Decreases are not highlighted in order to emphasize areas of concern for future work. Net area is presented as square meters for 2011 and 2016/2017. "++" indicates an increase from no recorded observations in 2011. "?" indicates a change that may be spurious.

Agua Chinon / Loma Ridge					
Species	2011	2016-17	Change	Hrs Invested	Increase
Cirsium vulgare	37	-	-100%		
Conium maculatum	3,577	148	-96%		?
Cortaderia selloana	561	72	-87%	7.3	
Cynara cardunculus	56,802	1,170	-98%	325.5	
Encelia farinosa	24,570	29,117	19%		
Foeniculum vulgare	218	1,110	409%	4.2	↑↑
Glebionis coronaria	28	-	-100%	25.0	
Marrubium vulgare	5,282	5,550	5%	8.0	
Nerium oleander	-	2	++		
Nicotiana glauca	36,550	8,745	-76%	404.1	
Pennisetum setaceum	2,900	11,909	311%	18.9	↑↑
Pinus spp.	2,304	-	-100%		?
Ricinus communis	3,102	608	-80%	579.7	
Schinus molle	151	104	-31%		
Tamarix ramosissima	3,545	1,160	-67%	62.7	
Washingtonia robusta	113	4	-96%	0.3	?
Total	139,742	59,698	-57%	1,436	

Notes:

- IRC manages 67% of this Management Unit by area, 95% by area of invasive plants.
- Control effort of *Cortedaria selloana, Cynara cardunculus, Glebionis coronaria, Nicotiana glauca, Ricinus communis,* and *Tamarix ramosissima* were correlated with substantial decreases (67-100%) in target plant cover.
- *Glebionis coronaria* was eradicated locally (based on helicopter data) .
- Worrisome trends include the increase of *Foeniculum vulgare* and *Pennisetum setaceum*.

Black Star Canyon					
Species	**2011**	**2016-17**	**Change**	**Hrs Invested**	**Increase**
Arundo donax	142	1,250	778%	78.4	↑↑
Cirsium vulgare	3	1,592	55195%	2.4	↑↑↑
Conium maculatum	6,918	-	-100%	6.0	?
Cortaderia selloana	42	5	-87%	0.5	
Cynara cardunculus	52,166	3,582	-93%	125.9	
Foeniculum vulgare	3,739	980	-74%	89.1	
Lepidium latifolium	73	6,349	8628%	13.4	↑↑↑
Marrubium vulgare	227	271	19%	0.3	
Nerium oleander	2	46	1860%	1.6	↑↑↑
Nicotiana glauca	1,265	47,714	3671%	129.3	↑↑↑
Pennisetum setaceum	1	175	14426%	1.1	↑↑↑
Phoenix canariensis	74	18	-75%		
Pinus spp.	2,698	1,207	-55%		?
Ricinus communis	48	407	745%	45.5	↑↑
Schinus molle	46	-	-100%		
Schinus terebinthifolius	77	4	-95%		
Spartium junceum	2,568	20	-99%	156.3	
Tamarix ramosissima	563	24,389	4232%	29.2	↑↑↑
Washingtonia robusta	67	8	-88%		
Total	70,720	88,018	24%	679	

Notes:

- IRC manages 57% of this Management Unit by area, 19% by area of invasive plants.
- Control effort of *Cynara cardunculus, Foeniculum vulgare, and Spartium junceum* were correlated with substantial decreases (89-93%) in target plant cover.
- Worrisome trends include the increase of *Arundo donax, Cirsium vulare, Lepidium latifolium, Nicotiana glauca, Pennisetum setaceum, Ricinus communis* and *Tamarix ramosissima* and are largely associated with sections of Santiago Creek immediately upstream of Irvine Lake.

Coal Canyon / Chino Hills

This Management Unit was not mapped in the 2016-17 helicopter survey, so no comparison is presented.

Fremont Canyon					
Species	**2011**	**2016-17**	**Change**	**Hrs Invested**	**Increase**
Arundo donax	-	-	0%	0.0	
Cirsium vulgare	-	-	0%	0.1	
Cortaderia selloana	8	2	-72%	1.7	
Cynara cardunculus	8,997	97	-99%	41.4	
Encelia farinosa	-	530	++		↑↑↑
Foeniculum vulgare	10	492	4633%	16.4	↑↑↑
Lepidium latifolium	-	-	0%	0.0	
Marrubium vulgare	4,161	1,033	-75%		
Nerium oleander	-	-	0%	0.9	
Nicotiana glauca	794	1,423	79%	276.2	↑
Pennisetum setaceum	8	2,007	23901%	1.3	↑↑↑
Ricinus communis	1	-	-100%	18.5	
Schinus molle	-	382	++		↑↑↑
Tamarix ramosissima	-	33	++	7.9	
Washingtonia robusta	73	2	-97%		**?**
Total	14,053	5,999	-57%	364	

Notes:

- IRC manages 84% of this Management Unit by area, 78% by area of invasive plants.
- Control effort of *Cortedaria selloana, Cynara cardunculus,* and *Ricinus communis* were correlated with substantial decreases (72-100%) in target plant cover.
- Worrisome trends include the increase of *Foeniculum vulgare* and *Pennisetum setaceum, and Tamarix ramosissima* (though acreage is small).
- The increase in *Schinus molle* should be investigated further.

Gypsum Canyon					
Species	2011	2016-17	Change	Hrs Invested	Increase
Ailanthus altissima	-	-	0%	3.7	
Centaurea solstitialis	2,080	3	-100%	265.3	
Cortaderia selloana	16	20	26%		
Cynara cardunculus	112	74	-34%		
Encelia farinosa		50,996	++		↑↑↑
Foeniculum vulgare	269	76	-72%	5.0	
Gazania linearis		261	++	0.1	↑↑↑
Lepidium latifolium	-	-	0%	5.2	
Marrubium vulgare	471	52	-89%		
Nerium oleander	1,579		-100%		
Nicotiana glauca	33,713	4,133	-88%	2.9	
Pennisetum setaceum		16,797	++		↑↑↑
Ricinus communis	2,487	15	-99%	3.0	
Schinus molle	1,032	623	-40%		
Tamarix ramosissima	117	4,271	3551%	1.4	↑↑↑
Washingtonia robusta		5	++		
Total	41,877	77,326	85%	287	

Notes:

- IRC manages 50% of this Management Unit by area, 22% by area of invasive plants.
- Control effort of *Centaurea solstitialis* was correlated with substantial decrease (+99%) in target plant cover.
- Worrisome trends include the increase of *Gazania linearis, Pennisetum setaceum,* and *Tamarix ramosissima.*
- Documentation across survey periods did not seem consistent for this management areas, based on several species being observed in only one or the other survey.

Limestone Canyon					
Species	**2011**	**2016-17**	**Change**	**Hrs Invested**	**Increase**
Ailanthus altissima	1	-	-100%	5.1	
Arundo donax	651	9	-99%		
Cirsium vulgare	298	1	-100%	4.8	
Cortaderia selloana	22	9	-61%	0.3	
Cynara cardunculus	58,614	9,128	-84%	739.6	
Encelia farinosa	2,482	3,391	37%		
Foeniculum vulgare	39,377	4,613	-88%	438.6	
Lepidium latifolium	-	37	++		
Marrubium vulgare	18,874	8,244	-56%	137.0	
Myoporum laetum	2	-	-100%		
Nicotiana glauca	2,169	890	-59%	144.8	
Pennisetum setaceum	1	205	36691%	1.0	↑↑↑
Phoenix canariensis	-	7	++		
Pinus spp.	74	347	367%		?
Ricinus communis	77	61	-21%	16.4	
Schinus molle	473	881	86%	0.0	↑↑
Spartium junceum	-	-	0%	0.3	
Tamarix ramosissima	121	51	-58%		
Washingtonia robusta	38	4	-89%	0.6	?
Total	123,273	27,878	-77%	1,488	

Notes:

- IRC manages 77% of this Management Unit by area, 71% by area of invasive plants.
- Control effort of *Ailanthus altissima, Cirsium vulgare, Cynara cardunculus,* and *Foeniculum vulgare* were correlated with substantial decreases (84-100%) in target plant cover.
- *Ailanthus* appears to have been locally eradicated, based on surveys.
- Worrisome trends include the increase of *Pennisetum setaceum* and *Schinus molle*.
- The increase in *Schinus molle* should be investigated further.

.

Santiago Creek					
Species	2011	2016-17	Change	Hrs Invested	Increase
Ailanthus altissima	-	-	0%	0.0	
Arundo donax	587	21	-96%	16.0	
Cirsium vulgare	1,030	131	-87%		
Conium maculatum	25,521	-	-100%		?
Cortaderia selloana	4	-	-100%	0.0	
Cynara cardunculus	15	7	-54%	4.2	
Encelia farinosa	13	11	-11%		
Foeniculum vulgare	1,729	502	-71%	128.9	
Gazania linearis	323	41	-87%	2.8	
Lepidium latifolium	2,129	-	-100%	4.8	
Marrubium vulgare	109	463	325%	0.4	↑↑
Nerium oleander	6	2	-73%		
Nicotiana glauca	278	2,950	963%	14.0	↑↑
Pennisetum setaceum	844	4,629	448%	8.4	↑↑
Pinus spp.	1,098	453	-59%		?
Ricinus communis	294	962	228%	16.6	↑↑
Schinus molle	1,375	1,207	-12%	0.2	
Schinus terebinthifolius	135	-	-100%		
Spartium junceum	7,248	152	-98%	162.6	
Tamarix ramosissima	267	503	88%	72.4	↑
Washingtonia robusta	46	1	-98%	0.2	?
Total	43,051	12,034	-72%	431	

Notes:

- IRC manages 47% of this Management Unit by area, 99% by area of invasive plants.
- Control effort of *Arundo donax, Foeniculum vulgare, and Spartium junceum* were correlated with substantial decreases (71-98%) in target plant cover.
- Worrisome trends include the increase of *Nicotiana glauca, Pennisetum setaceum, Ricinus communis, and Tamarix ramosissima.*

Silverado Canyon					
Species	**2011**	**2016-17**	**Change**	**Hrs Invested**	**Increase**
Ailanthus altissima	-	-	0%	3.8	
Arundo donax	14	-	-100%	28.3	
Cirsium vulgare	3	-	-100%	0.6	
Conium maculatum	173	-	-100%	0.6	**?**
Cortaderia selloana	-	-	0%	2.1	
Cynara cardunculus	2	-	-100%	6.4	
Foeniculum vulgare	1,409	159	-89%	83.2	
Lepidium latifolium	190	-	-100%	92.6	
Marrubium vulgare	15	21	43%		
Nerium oleander	7	2	-75%	1.7	
Nicotiana glauca	-	-	0%	15.2	
Pennisetum setaceum	-	-	0%	9.6	
Pinus sp.	790	2	-100%	1.5	
Ricinus communis	29	26	-11%	96.6	
Schinus molle	119	96	-19%	0.5	
Spartium junceum	15	17	17%	88.2	
Tamarix ramosissima	29	1	-98%	23.0	
Washingtonia robusta	-	1	++	0.4	
Total	2,794	326	-88%	454	

Notes

- IRC manages 38% of this Management Unit by area, 100% by area of invasive plants.
- Control effort of *Arundo donax, Circium vulgare, Cynara cardunculus, Foeniculum vulgare, Lepidium latifolium, Nerium oleander, Pinus* spp., and *Tamarix ramosissima were* correlated with substantial decreases (75-100%) in target plant cover.
- Surveys did not observe *Ailanthus altissima, Cortaderia selloana, Nicotiana glauca,* and *Pennisetum setaceum*, which were all present in the IPMU and controlled.
- There are no worrisome trends in this IPMU, with the exception of a slight increase in *Marrubium vulgare* (not prioritized) and *Spartium junceum*.

Weir / Blind Canyon					
Species	**2011**	**2016-17**	**Change**	**Hrs Invested**	**Increase**
Ailanthus altissima	3,062	366	-88%		
Arundo donax	33	3,017	9075%	0.1	↑↑↑
Centaurea solstitialis	-	2	++		
Cirsium vulgare	-	5,461	++		↑↑↑
Conium maculatum	29,934	-	-100%		?
Cortaderia selloana	130	549	323%		↑↑
Cynara cardunculus	47,858	1,724	-96%	227.5	
Encelia farinosa	122	292	139%		↑↑
Foeniculum vulgare	3,885	898	-77%	14.1	
Lepidium latifolium	220	2,543	1058%		↑↑↑
Marrubium vulgare	299	511	71%		↑
Nicotiana glauca	9,217	2,694	-71%	168.2	
Pennisetum setaceum	1,777	20,745	1067%	45.7	↑↑↑
Phoenix canariensis	351	170	-52%		
Pinus sp.	-	529	++		?
Ricinus communis	4,816	10,885	126%	66.3	↑↑
Schinus molle	37	476	1180%		↑↑↑
Tamarix ramosissima	697	11,715	1581%		↑↑↑
Washingtonia robusta	-	7	++		
Total	102,439	62,584	-39%	522	

Notes:

- IRC manages 58% of this Management Unit by area, 13% by area of invasive plants.
- Control effort of *Cynara cardunculus, Foeniculum vulgare and Nicotiana glauca* were correlated with substantial decreases (71-96%) in target plant cover.
- Worrisome trends include substantial increases in cover of *Arundo donax, Cirsium vulgare, Cortaderia selloana, Lepidium latifolium, Pennisetum setaceum, Ricinus communis,* and *Tamarix ramosissima.*

West Loma Ridge / Peters Canyon					
Species	2011	2016-17	Change	Hrs Invested	Increase
Arundo donax	-	97	++		↑↑↑
Cortaderia selloana	13,728	7,479	-46%		
Cynara cardunculus	31,729	3,647	-89%	162.0	
Encelia farinosa	220	-	-100%		
Foeniculum vulgare	9,628	3,522	-63%	111.3	
Marrubium vulgare	4,159	1,031	-75%	1.1	
Nerium oleander	-	121	++		↑↑↑
Nicotiana glauca	34,405	8,658	-75%	58.1	
Pennisetum setaceum	818	1,319	61%	7.6	↑
Phoenix canariensis	1,340	415	-69%		
Pinus spp.	-	2,071	++		?
Ricinus communis	660	203	-69%	0.0	
Schinus molle	-	1,546	++		↑↑↑
Tamarix ramosissima	1,403	1,250	-11%		
Washingtonia robusta	37	1	-97%	0.1	?
Total	98,127	31,360	-68%	340	

Notes:

- IRC manages 66% of this Management Unit by area, 83% by area of invasive plants.
- Control effort of *Cynara cardunculus, Nicotiana glauca* were correlated with substantial decreases (75-89%) in target plant cover.
- Worrisome trends include the increase se of *Arundo donax* and *Pennisetum setaceum.*
- Increases in *Nerium oleander* and *Schinus molle* should be investigated further.
- Note that Peters Canyon was not included in the comparison because it was not flown in 2016/2017.

Whiting Ranch					
Species	2011	2016-17	Change	Hrs Invested	Increase
Cortaderia selloana	49	307	531%	4.1	↑↑
Cynara cardunculus	35,340	1,658	-95%	26.7	
Encelia farinosa	-	19	++		
Foeniculum vulgare	61	356	480%		↑↑
Marrubium vulgare	65,848	25,205	-62%		
Myoporum laetum	18	-	-100%		
Nicotiana glauca	30,582	10,608	-65%	0.8	
Pennisetum setaceum	19	94	389%	1.5	↑↑
Schinus molle	-	291	++		↑↑↑
Tamarix ramosissima	3,288	2,826	-14%	0.5	
Washingtonia robusta	13	4	-69%		?
Total	135,218	41,368	-69%	34	

Notes:

- IRC manages 8% of this Management Unit by area, 8% by area of invasive plants.
- Control effort of *Cynara cardunculus* were correlated with a 95% decrease in its cover, though the limited hours reported cannot explain the full extent of its decline.
- Worrisome trends include the increase of *Cortaderia selloana, Foeniculum vulgare, Pennisetum setaceum, and Schinus molle.*
- Increase in *Schinus molle* should be investigated further.

Plant Species Found in One Survey Only

The preceding analyses compare data for those species mapped by both surveys. While that is the primary focus of this report, the surveys may provide additional information based on weed species that were observed in one helicopter survey but not the other. For instance, the following species were mapped in 2011 and not in 2016-17. This may indicate successful control work in the interim. (We are omitting species, such as *Atriplex semibaccata, Emex spinosa* and *Ehrharta erecta*, which were purposefully left out of the 2016/17 survey.)

Three species (*Limonium perezii* at 6355 m^2, *Myoporum laetum* at 20 m^2 and *Pittosporum undulatum* at 232 m^2) were found in 2011 but not 2016/2017. Given *that L. perezii* and *P. undulatum* were not listed to survey in 2016/2017 it is unclear whether they had disappeared or were just not recorded. Incidental control may have occurred for these species between 2011 and 2016/2017, though none was recorded.

The following species were mapped in 2016-17 and not 2011, which may indicate detections of new invasions (with the exception of *O. ficus-indica*, which was consciously not mapped in 2011):

Acacia sp.	382 m^2	in Agua Chinon/Loma Ridge, Black Star, Fremont, Whiting Ranch
Agave sp.	53 m^2	in Agua Chinon/Loma Ridge

Asphodelus fistulosus	19	m^2 in Agua Chinon/Loma Ridge
Ficus carica	3	m^2 in Whiting Ranch
Olea europaea	1,001	m^2 in Black Star, Santiago, Silverado
Opuntia ficus-indica	194	m^2 in Agua Chinon/Loma Ridge, West Loma Ridge/Peters
Parkinsonia sp.	20	m^2 in Limestone
Pennisetum clandestinum	4	m^2 in Silverado, Whiting Ranch

Conclusions

There is a lot to learn from the data collected via the 2011 and 2016/17 invasive plant helicopter surveys. To the degree that we accept the data as fairly accurate, we can deduce success stories as well as worrisome trends. And to the degree that the data seem inaccurate, we can make recommendations for future use of helicopter surveys and labor hour tracking.

Changes in cover of species were due both to increases or decreases in existing stand size and the emergence or disappearance of new stands (aka populations) of each species. Although a direct comparison of populations could not be conducted because of differences in mapping methodology across both years, qualitative comparisons and coarse-scale quantitative comparisons were possible. Overall, significant net progress was made across for the following focal species: *Centaurea solstitialis*, *Cynara cardunculus*, *Glebionis coronaria*, and *Spartium junceum* were targeted for control and all declined by over 90% and. *Conium maculatum* also declined significantly but its decline could not be attributed to control efforts.

Some species showed significant increases in net area. Fountaingrass (*Pennisetum setaceum*) and brittlebush (*Encelia farinosa*) each expanded by more than ten acres. Whereas fountaingrass was aggressively treated in places, brittlebush was not. We do not include expansion of *Encelia farinosa* in the list of species of concern, because it is regionally native, has unknown impact, is already widely established, and must be evaluated further before embarking on strategic control efforts. Three other species (*Lepidium latifolium, Arundo donax* and *Ricinus communis*) increased despite regular control activities in localized areas. The causes and locations of these increases should be researched more thoroughly.

When viewed as percent change in area, some species appear to be near 100% eradication—poison hemlock (*Conium maculatum*), yellow starthistle (*Centaurea solstitialis*), Brazilian pepper tree (*Schinus terebinthifolius*) and Spanish broom (*Spartium junceum*) have all been reduced by 98% or greater. On the other hand, some plant species showed a big increase by percent. *Pennisetum setaceum* increased eightfold. Bull thistle, (*Cirsium vulgare*) and salt cedar (*Tamarix* sp) increased fourfold, while perennial pepperweed (*Lepidium latifolium*), giant reed (*Arundo donax*) and brittlebush (*Encelia farinosa*) all doubled in area.

Reductions in cover were associated with control work and reflected a decrease in existing stand size in *Centaurea solstitialis, Cynara cardunculus,* and *Spartium junceum* and a decrease in the distribution of populations observed for *C. cardunculus* and *S. junceum* (data not shown). Decreases in cover for *F.*

vulgare and *N. glauca* were associated with local successes that masked the proliferations of new, small stands in other regions where these species were not prioritized.

Some species decreased significantly with no significant reporting of control. Either substantial work was done on these species by Orange County Parks or changes were the result of differences in mapping methodology or annual/seasonal variation.

With the exception of *Marrubium vulgare* and *Conium maculatum*, all species reported as having decreased in area are relatively uncommon in the study area and tend to occur as isolated stands. The 2016/2017 survey appeared to estimate net area in isolated stands more conservatively than the 2011 survey, leading to an apparent reduction in net area not driven by a reduction in the distribution of these species (in several cases there in an increase), but rather driven by a reduction of the net area (or percent cover) of each stand. Therefore, when looking at species-level trends across survey years, the distribution of each species should be carefully compared in order to avoid spurious conclusions.

As described above, *Marrubium* decreased in net area but increased in its distribution across the study area. Multiple new, small populations were found in areas such as Weir Canyon. *Conium'*s decrease in net acreage remains a mystery (see species assessment above).

There were notable cases where species appeared to have spread significantly. These include:

- ***Arundo donax*** is spreading in Black Star Canyon, Weir/Blind Canyon, and West Loma Ridge / Peters Canyon. See species assessment.
- ***Cirsium vulgare*** is spreading in Black Star Canyon.
- ***Cortaderia selloana*** is spreading at Weir/Blind Canyon and Whiting Ranch.
- ***Encelia farinosa*** is expanding, in particular in Gypsum Canyon.
- ***Foeniculum vulgare*** is spreading in Agua Chinon / Loma Ridge, Fremont Canyon and Whiting Ranch despite successful control efforts in other IPMUs.
- ***Nicotania glauca*** is spreading Black Star Canyon, Fremont Canyon, and Santiago Creek despite successful control efforts in other IPMUs.
- ***Pennisetum setaceum*** is spreading extensively everywhere.
- ***Ricinus communis*** is spreading in Black Star Canyon, Santiago Creek, and Weir/Blind Canyon despite successful control efforts in other IPMUs.
- ***Schinus molle*** may be spreading in Fremont Canyon, Limestone Canyon, Weir/Blind Canyon, West Loma Ridge / Peters Canyon, and Whiting Ranch. Note that some expansion may be due to planting and that control is complicated by this species still being used for landscaping regionally.

- ***Tamarix ramosissima*** is spreading in Black Star Canyon, Fremont Canyon, Gypsum Canyon, Santiago Creek, and Weir/Blind Canyon.

Whereas not all species listed above can be prioritized for control, their expansion and potential risk to protected habitat should be reviewed and addressed as needed. Species such as *Arundo*, *Pennisetum* and *Tamarix* are listed as highly invasive and impactful species and their expansion is important to address. Although increases in *Pinus* sp. were observed, this species was removed because increases were probably due to mapping differences along edge habitat.

The same worrisome trends organized by IPMU, leaving out *Pennisetum setaceum* which is spreading everywhere:

- **Agua Chinon / Loma Ridge** - *Foeniculum vulgare* is spreading.
- **Black Star Canyon** - *Arundo donax, Cirsium vulgare, Nicotania glauca, Ricinus communis,* and *Tamarix* sp are spreading.
- **Coal Canyon / Chino Hills** – no alerts, but this IPMU was not mapped in the 2016/17 survey.
- **Fremont Canyon** - *Foeniculum vulgare, Nicotania glauca, Schinus molle* and *Tamarix* sp are spreading.
- **Gypsum Canyon** - *Encelia farinosa* and *Tamarix* sp are spreading.
- **Limestone Canyon** - *Schinus molle* is spreading.
- **Santiago Creek** - *Nicotania glauca, Ricinus communis,* and *Tamarix* sp are spreading.
- **Silverado Canyon** – no big alerts.
- **Weir / Blind Canyon** - *Arundo donax, Cortaderia selloana, Ricinus communis, Schinus molle* and *Tamarix* sp are spreading.
- **West Loma Ridge / Peters Canyon** - *Arundo donax,* and *Schinus molle* are spreading.
- **Whiting Ranch** - *Cortaderia selloana, Foeniculum vulgare,* and *Schinus molle* are spreading.

In particular, regions of concern within the IPMUs where significant increases of several species were observed include: (1) the upstream section of Irvine lake that is reserved for mitigation (Black Star IPMU), (2) the western section of Irvine Regional Park (Weir/Blind IPMU), (3) Santiago Oaks (Weir/Blind IPMU), and (4) Weir Canyon (Weir/Blind IPMU), and (5) Gypsum Canyon.

Utility of Helicopter Surveys

Helicopter surveys were useful in providing a regional snapshot in time of the abundance and distribution of key invasive species (at least those species which are large enough to be detectable from 30-100' up). They are less expensive than foot surveys for large areas, particularly in difficult topography or dense vegetation. However, they can be constrained by human infrastructure, weather, availability of specialized contractors, and access permissions. Aerial surveys may find more populations in grasslands

than in woodlands or riparian areas due to limitations they have in viewing understory vegetation. Helicopter surveys have also been found to map larger polygons than a foot crew because of their aerial view (IRC, unpublished data). Nonetheless, the two consecutive surveys compared here provided a remarkably consistent assessment of invasive plant cover and species' identity (see Table 3).

Helicopter survey data collected at a five-year interval are useful both used alone and when paired with data on time invested in controlling each species in each IPMU. The time span was sufficient both to track notable successes in controlling some species and to confirm and map the substantial spread of other species. Some discrepancies between the two mapping methodologies were apparent and complicated our interpretation of trends we observed. These can at least in part be corrected by standardizing helicopter mapping methodology. Observers could improve accuracy by: (1) ensuring that mapping occurs at the same time of year (adjusted relative to that year's rain pattern), (2) documenting criteria used to estimate net and gross acreage by species and calibrating accordingly, (3) documenting specifically which species were surveyed for and not found in addition to which were added to the original list after each survey, and (4) maintaining a standardized transect spacing distance and a detailed log of any areas that could not be surveyed thoroughly.

Population mapping protocol varied slightly across mapping events and therefore complicated analysis of changes in number of populations and net acreage. Specifically, surveys differed in net acreage estimation and tendency to map populations as points versus polygons, versus lines. Regardless of survey methodology, changes in species cover over time should always be studied carefully in order to avoid spurious conclusions. We recommend that all future helicopter surveys include a short final report to document exact methodology and key field observations.

Spread of existing populations and emergence of new populations were effectively tracked using helicopter mapping. Cover estimates can be generalized in future analyses to provide an assessment of habitat health at a relatively fine scale. Helicopter surveys are currently the only tool available to local land managers monitor change in invasive plant cover at a species level over a large area, especially one with remote, difficult to access sites.

Utility of Labor Tracking

IRC provided estimates of labor hours invested to treat the 24 species evaluated in this study. Person hours were either reported directly by polygon, or divided out across all polygons visited based on either the area or number of plants treated. Effects of control work were observable from decreases in area and number of populations. Expansions of species were observable as well, from areas where control work was not implemented or not successful or not aiming to reduce the plant across the whole area.

When associated with estimates of labor hours invested for control, reduction in net acreage demonstrates the beneficial impacts of the control work (e.g., for *Centaurea solstitialis*, *Cynara cardunculus* and *Spartium junceum*). Additional comparisons were hampered by: absence of data on control effort from entities other than IRC; incomplete documentation of control work; potentially

inaccurate approximation of labor effort when multiple polygons were visited and person hours had to be estimated for each population controlled based on more general labor reports of area treated.

As a result, we likely underestimated overall time invested as well as time dedicated to some populations with low net area (since that was the basis for our estimates of time spent). Newer methodologies for tracking control by polygon directly in the field will reduce inaccuracies in reporting control effort. Consistent tracking protocols that are now shared across land managers will further improve documentation and allow land managers to better track success and identify potential causes for lack of success.

Spatial Variation in Control and Mapping Effort

Invasive Plant Management Units (IPMUs) were developed, to the degree possible, to match larger sub-watersheds and are not aligned with property boundaries. Therefore they include multiple land owners and/or managers and, consequently, substantial potential variation in management effort. IPMUs are useful in presenting a land manager with the larger spatial context of invasive plant issues that extend beyond their own jurisdictional borders but can complicate tracking success at a local scale. In the future, effort and success for key high-priority species can be analyzed using property and/or management boundaries as well as at the IPMU scale.

Summary

Helicopter surveys provide an efficient and elegant method by which to track landscape-level changes in invasive plant distributions. They can successfully be used to not only identify populations of high-priority species that may otherwise not be found, but also to track success of control efforts (or lack thereof) over time. Their utility is challenged by the limited availability and logistical complications associated with conducting aerial surveys with skilled contractors, as well as by the lack of full consistency across (or within) surveys. When used in combination with digital treatment tracking, surveys can provide a third-party assessment of the effectiveness of control efforts. Information on the reserve-wide distribution of invasive species is valuable information. When combined with information on species' risk of spread and relative ecological impacts as well as site-specific knowledge of control effort, the resulting analysis provides a founding for improving the regional effectiveness of invasive plant management.