Aerial Invasive Plant Survey with Treatment Prioritization Analysis & Mule Deer Survey

Coastal Subregion of the Orange County Natural Community Conservation Plan

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NATURE RESERVE of ORANGE COUNTY

Wildlands Conservation Science

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Acronyms and Abbreviations

CDFW	California Department of Fish and Wildlife
CNPS	California Native Plant Society
GIS	Geographic Information Systems
GPS	Global Positioning System
MCV	Manual of California Vegetation (2009)
NRI	Native Range, Inc.
NROC	Nature Reserve of Orange County
NCCP	Coastal Subregion of the Orange County Natural Community Conservation Plan
PAF	Plant Assessment Form
WCS	Wildlands Conservation Science, LLC.

1.0 Introduction

For the last 20 years, Nature Reserve of Orange County (NROC), together with partnering organizations (OC Parks, City of Irvine, City of Newport Beach, California State Parks, Irvine Ranch Conservancy, and The Nature Conservancy), have implemented a targeted invasive plant (weed) control program within the Coastal Subregion of the Orange County Natural Community Conservation Plan (NCCP). Through the program, thousands of acres of artichoke thistle (*Cynara cardunculus*) and other targeted invasive plant species have been treated and controlled. With the program's success in accomplishing its goals and scheduled end in 2015, priorities for the Coastal Reserve's invasive plant control program must now be redefined and the focus of the program broadened to include a growing list of emerging weeds.

To achieve these goals, the NROC recognized that an updated survey of the distribution of artichoke thistle and other established and emerging weeds was needed. In Spring 2014, NROC contracted Wildlands Conservation Science, LLC (WCS) to perform aerial weed surveys and to comprehensively document the population size and spatial distribution of artichoke thistle and an additional 38 invasive plant species from within 17,420 acres of habitat in the NCCP's Coastal Subregion (Table 1; Figure 1). The resulting geospatial weed data will be used by the NROC and land managers to evaluate the effectiveness of current weed monitoring practices, identify emerging weed populations, and strategically plan future weed control actions.

In addition, WCS was contracted to systematically record all southern mule deer (*Odocoileus hemionus fuliginatus*) observed while flying aerial weed transects to provide a "snapshot" estimate of mule deer populations within the NCCP's Coastal Subregion.

This report summarizes the results of the NCCP's Coastal Subregion weed and mule deer survey conducted during a 12-day period (9 to 20 June 2014) and provides an invasive plant prioritization for the 2,133 weed population stands documented during the project.

Table 1. List of 39 invasive plant species that WCS was contracted to survey for and document within the NCCP Coastal Subregion. WCS detected and mapped an additional 24 species.

#	Species	Common Name	#	Species	Common Name
1	*Araujia sericifera*	Bladderflower	33	*Lepidium latifolium*	Perennial Pepperweed
2	*Acacia cyclops*	Cyclops Acacia	34	*Limonium ramosissimum*	Algerian Sea Lavender
3	*Agave americana*	Century Plant	35	*Limonium sinuatum*	Statice
4	*Ailanthus altissima*	Tree of Heaven	36	*Marrubium vulgare*	Horehound
5	*Arundo donax*	Giant Reed	37	*Myoporum laetum*	Lollypop Tree
6	*Asphodelus fistulosus*	Onionweed	38	*Nerium oleander*	Oleander
7	*Atriplex semibaccata*	Australian Saltbush	39	*Nicotiana glauca*	Tree Tobacco
8	*Brassica sp.*	Unknown Mustard	40	*Olea europaea*	Olive
9	*Brassica tournefortii*	Sahara Mustard	41	*Opuntia ficus-indica*	Mission Cactus
10	*Buddleja davidii*	Butterflybush	42	*Paraserianthes lophantha*	Plume Acacia
11	*Cactoideae sp.*	Unknown Cactus	43	*Pennisetum setaceum*	Fountain Grass
12	*Callistemon sp.*	Bottlebrush	44	*Phalaris sp.*	Hardinggrass
13	*Carduus pycnocephalus*	Italian Thistle	45	*Philadelphus lewisii*	Mock Orange
14	*Carpobrotus edulis*	Iceplant	46	*Phoenix canariensis*	Canary Island Date Palm
15	*Centaurea solstitialis*	Yellow Starthistle	47	*Picris echioides*	Prickly Sowthistle
16	*Cirsium vulgare*	Bull Thistle	48	*Pinus sp.*	Unknown Pine Tree
17	*Conium maculatum*	Poison Hemlock	49	*Piptatherum miliaceum*	Smilo Grass
18	*Cortaderia selloana*	Pampas Grass	50	*Ricinus communis*	Castor Bean
19	*Cynara cardunculus*	Artichoke Thistle	51	*Robinia pseudoacacia*	Black Locust
20	*Cyperus papyrus*	Papyrus	52	*Schinus molle*	Peruvian Pepper Tree
21	*Echium candicans*	Pride of Madeira	53	*Schinus terebinthifolius*	Brazilian Pepper Tree
22	*Ehrharta calycina*	Veldt grass	54	*Silybum marianum*	Milk Thistle
23	*Emex spinosa*	Spiny Emex	55	*Spartium junceum*	Spanish Broom
24	*Encelia farinosa*	Brittlebush	56	*Stipa trichotoma*	Mexican Feather Grass
25	*Eucalyptus sp.*	Eucalyptus	57	*Tamarix sp.*	Tamarisk
26	*Foeniculum vulgare*	Fennel	58	*Tragopogon porrifolius*	Salsify
27	*Gazania sp.*	Gazania	59	*Tree sp.*	Unknown Tree
28	*Glebionis coronaria*	Garland Chrysanthemum	60	*Tropaeolum majus*	Garden Nasturtium
29	*Grass sp.*	Unknown Grass	61	*Ulmus parvifolia*	Chinese Elm
30	*Hedera sp.*	Unknown Ivy	62	*Washingtonia robusta*	Mexican Fan Palm
31	*Hypericum canariense*	Canary Island Saint John's Wort	63	*Yucca sp.*	Unknown Yucca
32	*Lactuca serriola*	Wild Lettuce			

BLACK TEXT= Species listed in the Statement of Work DETECTED during the surveys
TURQUOISE TEXT= Species listed in the Statement of Work NOT DETECTED during the surveys
GREEN TEXT= Species or taxa NOT LISTED in the Statement of Work but detected during the surveys

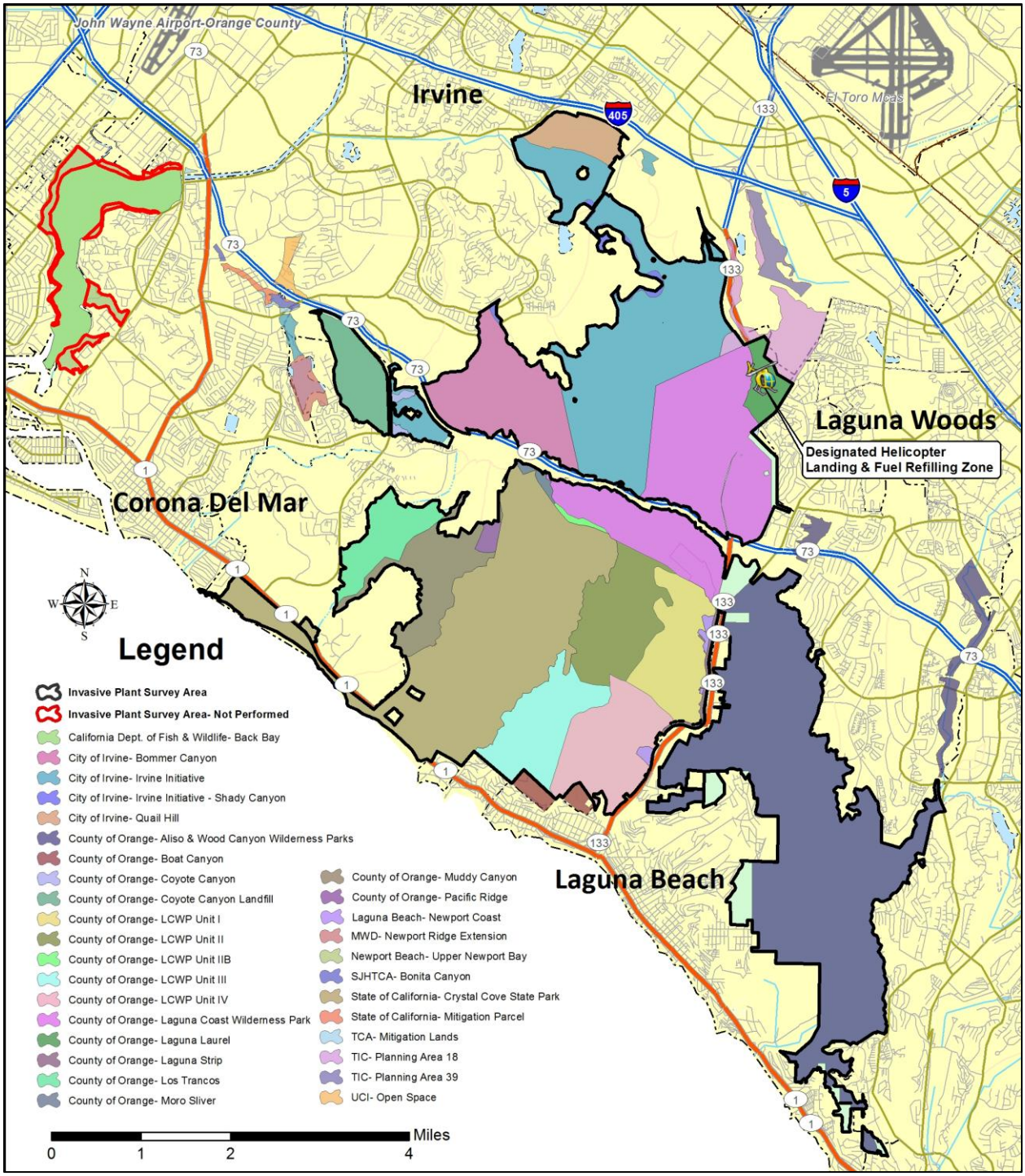

Figure 1. Aerial weed survey area within the Coastal Subregion of the Orange County NCCP and adjacent protected areas. Note: The marginal habitat surrounding the Upper Newport Bay was not surveyed due to flight restrictions imposed by the nearby John Wayne Airport.

2.0 Survey Methodology

2.1 Invasive Weed Survey Methodology

On June 9th, 2014 the project staff mobilized at the designated landing and fuel refilling zone (Figure 1). No other landing sites were utilized during the project. Aerial surveys began that day after a pre-project briefing with NROC coordinators Dr. Milan Mitrovich (Science Coordinator at the NROC) and Dr. Jutta Burger (Managing Director, Science and Stewardship at the Irvine Ranch Conservancy) along with local fire and law enforcement representatives. The weed survey was conducted over 12 consecutive days, ending on June 20th. However, a general flight restriction was imposed on June 14th due to a "short notice" fundraising visit to Laguna Beach by President Barack Obama. On that day, on-the-ground surveys were conducted along Laguna Canyon Road to obtain a quality survey of the area while reducing the need for helicopter disturbance along that busy traffic route.

A team of four individuals conducted the project, which included: Native Range Inc. (NRI) helicopter pilot (Dean Graham), botanical surveyors [Steve Junak (9 to 14 June) and Sarah Ratay (15 to 20 June)] and Geographic Information Systems (GIS) mapper and project coordinator (Morgan Ball). All surveyors have professional botanical training and they and the pilot have extensive experience surveying invasive plants in California from helicopters. Project coordination occurred via daily cellular phone calls and text messages between Morgan Ball and Milan Mitrovich to discuss project progression, notifications, and challenges.

Figure 2. Botanical surveyors demonstrating ease of detection and maneuverability at 15-feet altitude in a Schweizer-333 turbine-helicopter.

Aerial surveys were conducted using a Schweizer-333 turbine-helicopter. This helicopter model has the lowest noise signature (85 db at 100 feet above the ground) in its class (small turbine helicopters). The spacious side-by-side seating configuration of the 333 is ideal for botanical surveys allowing both surveyors and pilot to comfortably scan the entire terrain. The 333 is a stable platform due to its power and maneuverability which enables low level flights. During the surveys the terrain was flown systematically (at approximately 15 to 20 mph) and between 15 to 150-feet above the ground. However, when surveying over coastal scrub and patches of native Opuntia spp. the helicopter flew no lower than 100-feet of altitude to reduce the risk of causing early fledging of passerine birds. The surveyors found that flying between 75 to 100 feet above the ground in most situations was ideal to detect the majority of the species surveyed. Aerial survey routes were digitally recorded to document effort and avoid recounting populations. Surveys were started no earlier than 7AM and were concluded no later than 6PM

each day to avoid low light conditions. On average, 5.5 hours of flight time were conducted each day and concluded no later than 6PM each day to avoid low light conditions.

Table 2. Attribute field information associated with the NCCP's Coastal Region invasive plant survey.

NROC_CoastalWeed_Polygon_June2014	
Field Name	***Attribute Description***
DATE	Date of the observation.
Com_Name	Common name of the documented population stand.
Species	Scientific name of the documented population stand.
NUM_INDV	Estimated number of plants within the documented population stand. Note: Some of the population stands fields are populated with the value "see cover" indicating that the number of individuals within the stand are quite high and could not be counted. The population total should therefore be inferred by the *AcresWeed* value.
POPDENSITY	The vegetative cover of the documented invasive plant species within the mapped polygon. The Daubenmire cover-classes were used to visually estimate cover within a range, i.e. 5-25% cover.
AGE_CLASS	The most common age of plants within the population stand. Age was divided into seedlings, saplings, mature or mixed age class.
ID_CONFIDE	Confidence level (High, Mod, Low) that the survey team was able to identify the documented invasive plant to species from the air.
SURVEYOR	The name of the surveyors recording the data and helicopter pilot.
COMMENTS	Miscellaneous note regarding the documented invasive plant population stand.
Acres	Total area (acres) of the polygon including the interstitial spaces between the documented invasive plants within a population.
AcresWeed	Net area (acres) covered by the documented invasive plants within a population stand, not including the interstitial spaces between plants. Calculated by multiplying the *POPDENSITY* x *Acres* values.
Rating	Plant ranking for the documented invasive plant according to California Invasive Plant Council (Cal-IPC 2006).
POINT_X	X coordinate of the polygon centriod in StatePlane California VI.
POINT_Y	Y coordinate of the polygon centriod in StatePlane California VI.
StandID	Individual stand identification code.
NROC_CoastalWeed_Point_June2014	
All attribute fields same as in NROC_CoastalWeed_Polygon_June2014 except for those listed below:	
Field Name	***Attribute Description***
AreaLength	Linear length (feet) of the documented invasive plant population stand including the interstitial spaces between plants within a population.
AreaWidth	Linear width (feet) of the documented invasive plant population stand including the interstitial spaces between plants within the population.
Acres	Calculated area (acres) determined by multiplying *AreaLength* x *AreaWidth* then converting the square foot value to acres

Prior to the survey, a tablet PC operating ESRI ArcPad 10.0 GIS software and equipped with a global positioning system (GPS) was loaded with the survey boundaries overlaid on a moderate-resolution orthophotograph of the NCCP's Coastal Subregion. The tablet was also loaded with the coordinates of sensitive raptor nest locations to avoid. These data were used to guide the survey. Point and polygon data were recorded for each invasive plant population stand using

the tablet PC. For each invasive plant population stand recorded using a single data point, the length, width and ground cover density within that dimension was visually assessed from the air and recorded. A single invasive plant population stand was defined by a cluster or linear grouping plants of the same species spaced no more than approximately 100-ft apart. Populations with irregular shapes were recorded using polygons drawn on the Tablet PC using the helicopters location and the moderate-resolution orthophotograph for reference. Invasive plant cover was then estimated for the area within the larger polygon. The number of individuals and age-class of the plants were estimated for all invasive plant population stands regardless of shapefile type. The description of each data attribute contained within the GIS shapefiles for invasive plant point file entitled "NROC_CoastalWeed_Point_June2014" and the polygon file entitled "NROC_CoastalWeed_Polygon_June2014" are provided in Table 2.

2.2 Mule Deer Survey Methodology

When mule deer were detected during the survey, the number of antlered, antlerless and fawn deer were documented and mapped. Terrain was flown in a systematic fashion to reduce the likelihood animals would be counted twice. If animals were suspected of having already been mapped, they were not counted. Figure 3 provides a typical view of mule deer as seen from the helicopter. In addition to mule deer, WCS recorded the number and locations of coyote (*Canis latrans*) and bobcat (*Lynx rufus)* as well as the locations of active raptor nests.

These data were recorded on a point shape file entitled "NROC_CoastalWeed_Wildlife_June2014" with a single attribute comment field summarizing each documented observation.

Figure 3. Photo taken of an "antlered" buck mule deer from the Schweizer-333 helicopter in Aliso and Wood Canyons Wilderness Park

3.0 Survey Results

3.1 Invasive Weed Survey Results

During the 12 day field period, WCS flew a total of 1,599 survey miles and documented a total of 2,133 invasive plant population stands within 17,420 acres of the NCCP's Coastal Region (Figure 5). These infestations represent 54 different species (6 plant types indentified to genus and 3 types documented at a higher taxonomic level), 24 of which were not listed on the Statement of Work (Table 4). However, nine of the initial species proposed for survey were not detected (Table 4). The net ground-cover area of these invasive plant populations is estimated to be 223.9 acres growing within approximately 3,661.4 acres of infested habitat.

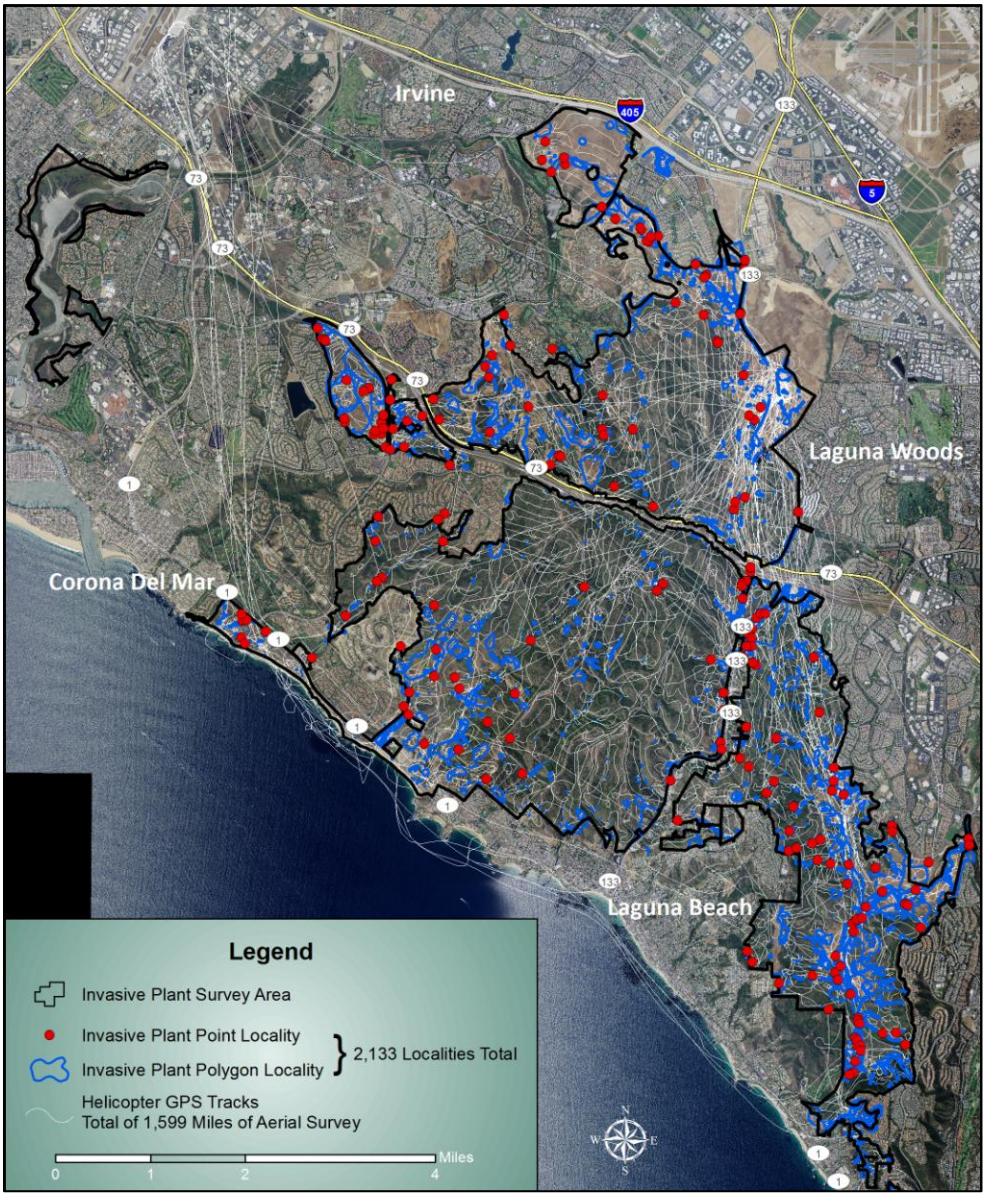

Figure 4. Map of invasive plants documented during aerial survey of the NCCP's Coastal Region.

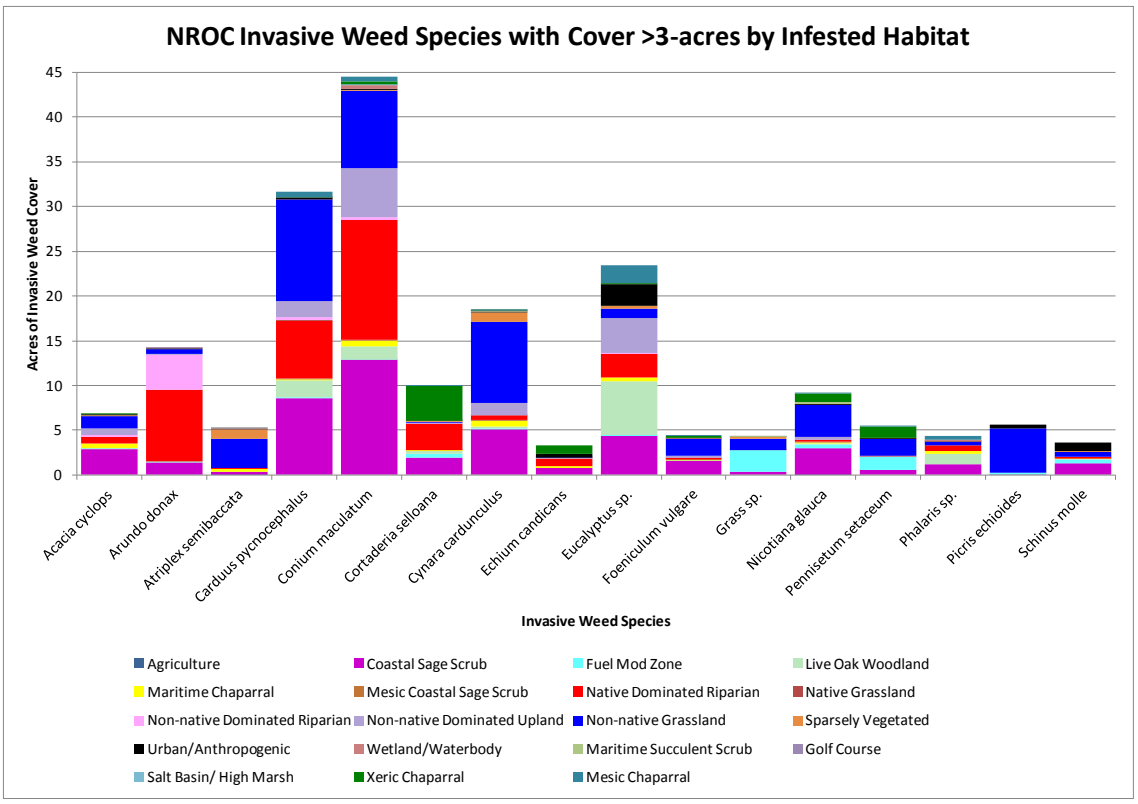

Figure 5. Total acres of invasive plant cover of each species with an infested size >3-acres by habitat.

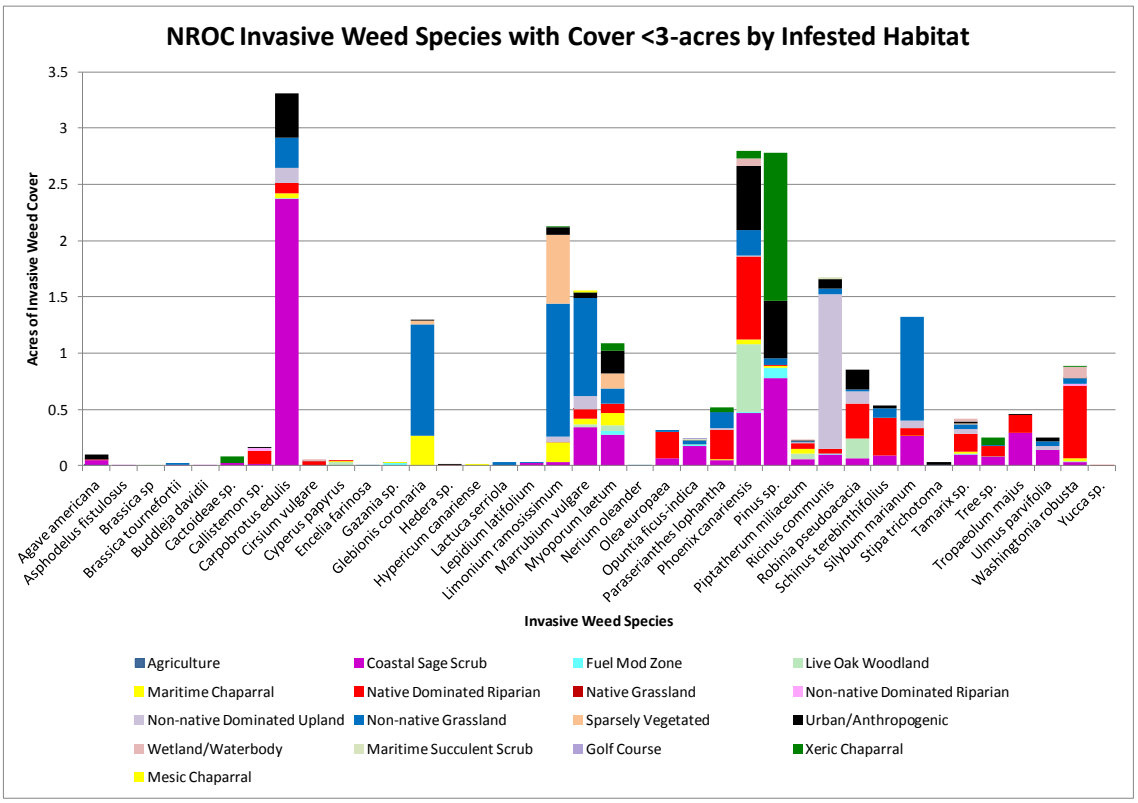

Figure 6. Total acres of invasive plant cover of each species with an infested size <3-acres by habitat.

Table 3. Summary of invasive plant populations stands documented during survey of the NNCP's Coastal Region (Figure 4).

#	Species	Common Name	# of Stands	Total Weed Acres	Acres Infested Habitat	#	Species	Common Name	# of Stands	Total Weed Acres	Acres Infested Habitat
1	*Araujia sericifera*	Bladderflower		*Not Found*		33	*Lepidium latifolium*	Perennial Pepperweed	3	0.03	1.96
2	*Acacia cyclops*	Cyclops Acacia	87	6.90	91.68	34	*Limonium ramosissimum*	Algerian Sea Lavender	4	2.12	211.92
3	*Agave americana*	Century Plant	9	0.10	0.31	35	*Limonium sinuatum*	Statice		*Not Found*	
4	*Ailanthus altissima*	Tree of Heaven		*Not Found*		36	*Marrubium vulgare*	Horehound	92	1.56	86.27
5	*Arundo donax*	Giant Reed	28	14.18	127.13	37	*Myoporum laetum*	Lollypop Tree	28	1.09	7.40
6	*Asphodelus fistulosus*	Onionweed	1	0.002	0.02	38	*Nerium oleander*	Oleander	3	0.04	0.56
7	*Atriplex semibaccata*	Australian Saltbush	59	5.35	388.00	39	*Nicotiana glauca*	Tree Tobacco	243	9.17	139.84
8	*Brassica sp.*	Unknown Mustard	1	0.0003	0.030	40	*Olea europaea*	Olive	7	0.31	0.35
9	*Brassica tournefortii*	Sahara Mustard	1	0.02	0.07	41	*Opuntia ficus-indica*	Mission Cactus	6	0.28	23.29
10	*Buddleja davidii*	Butterflybush	1	0.004	0.004	42	*Paraserianthes lophantha*	Plume Acacia	3	0.52	7.70
11	*Cactoideae sp.*	Unknown Cactus	1	0.09	1.72	43	*Pennisetum setaceum*	Fountain Grass	39	5.77	53.50
12	*Callistemon sp.*	Bottlebrush	2	0.16	15.54	44	*Phalaris sp.*	Hardinggrass	3	4.37	87.46
13	*Carduus pycnocephalus*	Italian Thistle	56	31.63	308.30	45	*Philadelphus lewisii*	Mock Orange		*Not Found*	
14	*Carpobrotus edulis*	Iceplant	26	3.31	35.76	46	*Phoenix canariensis*	Canary Island Date Palm	22	2.80	4.75
15	*Centaurea solstitialis*	Yellow Starthistle		*Not Found*		47	*Picris echioides*	Prickly Sowthistle	3	6.78	23.36
16	*Cirsium vulgare*	Bull Thistle	5	0.05	0.44	48	*Pinus sp.*	Unknown Pine Tree	16	2.78	5.59
17	*Conium maculatum*	Poison Hemlock	127	44.54	322.50	49	*Piptatherum miliaceum*	Smilo Grass	20	0.24	4.85
18	*Cortaderia selloana*	Pampas Grass	327	10.02	77.03	50	*Ricinus communis*	Castor Bean	26	1.70	3.31
19	*Cynara cardunculus*	Artichoke Thistle	407	18.92	1127.81	51	*Robinia pseudoacacia*	Black Locust	4	0.85	4.29
20	*Cyperus papyrus*	Papyrus	4	0.04	3.36	52	*Schinus molle*	Peruvian Pepper Tree	41	3.67	16.96
21	*Echium candicans*	Pride of Madeira	27	3.32	27.94	53	*Schinus terebinthifolius*	Brazilian Pepper Tree	13	0.54	2.92
22	*Ehrharta calycina*	Veldt grass		*Not Found*		54	*Silybum marianum*	Milk Thistle	12	1.32	6.45
23	*Emex spinosa*	Spiny Emex		*Not Found*		55	*Spartium junceum*	Spanish Broom		*Not Found*	
24	*Encelia farinosa*	Brittlebush	2	0.002	0.002	56	*Stipa trichotoma*	Mexican Feather Grass	12	0.03	0.59
25	*Eucalyptus sp.*	Eucalyptus	42	26.86	50.78	57	*Tamarix sp.*	Tamarisk	37	0.42	1.82
26	*Foeniculum vulgare*	Fennel	168	4.39	195.42	58	*Tragopogon porrifolius*	Salsify		*Not Found*	
27	*Gazania sp.*	Gazania	2	0.09	2.77	59	*Tree sp.*	Unknown Tree	12	0.25	4.62
28	*Glebionis coronaria*	Garland Chrysanthemum	1	1.30	129.93	60	*Tropaeolum majus*	Garden Nasturtium	5	0.45	1.76
29	*Grass sp.*	Unknown Grass	6	4.29	9.03	61	*Ulmus parvifolia*	Chinese Elm	16	0.25	1.41
30	*Hedera sp.*	Unknown Ivy	2	0.01	0.04	62	*Washingtonia robusta*	Mexican Fan Palm	63	0.89	41.02
31	*Hypericum canariense*	Canary Island Saint John's Wort	1	0.02	0.09	63	*Yucca sp.*	Unknown Yucca	1	0.001	0.001
32	*Lactuca serriola*	Wild Lettuce	6	0.03	1.69						

BLACK TEXT= Species listed in the Statement of Work DETECTED during the surveys
TURQUOISE TEXT= Species listed in the Statement of Work NOT DETECTED during the surveys
GREEN TEXT= Species or taxa NOT LISTED in the Statement of Work but detected during the surveys

3.2 Mule Deer Survey Results

In total, 45 mule deer (14 antlered, 29 antlerless and 2 fawns) were documented and mapped within the NCCP's Coastal Subregion. In addition, 9 adult and a pair of pup coyotes along with a single bobcat were recorded. Figure 5 provides a map of this documentation of wildlife. Although a substantial number of large raptor and raven nests were encountered during the survey, all but one red-tailed hawk (*Buteo jamaicensis*) cliff nest was inactive (Figure 5).

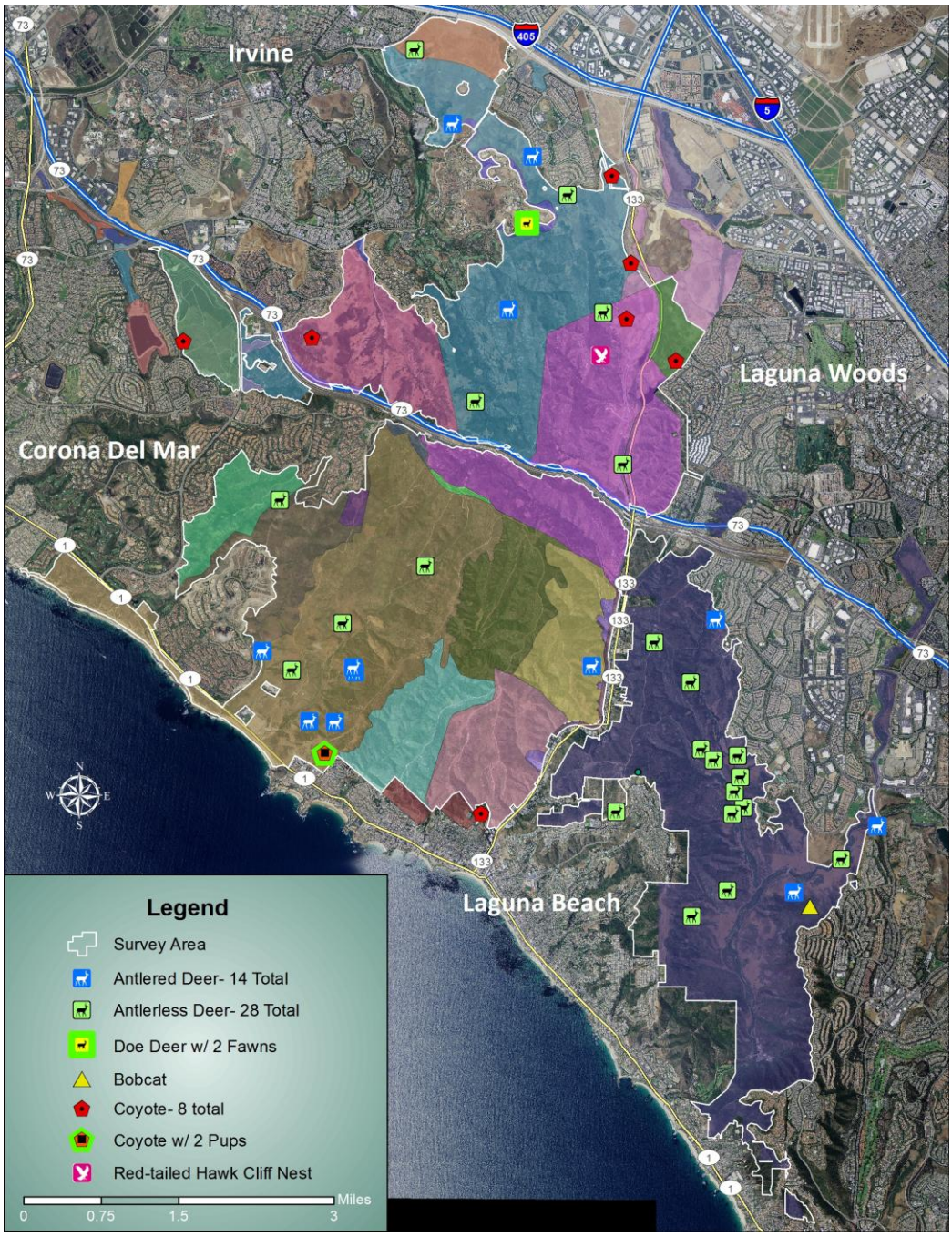

Figure 7. Map of mule deer and other vertebrate wildlife documented during the aerial weed survey.

4.0 Invasive Plant Discussion

4.1 Invasive Plant Prioritization Indexes

Managing multiple invasive plant species at the landscape level requires a systematic and transparent approach to effectively reach management objectives. Subjecting each species to a ranking scheme allows for consistent prioritization of key elements to be compared across all species. In order to develop a comprehensive prioritization scheme for treatment of the 54 detected weed species documented on the NCCP's Coastal Region, WCS first performed a detailed review of existing invasive plant species data and the habitat context in which they were found. Through this process, WCS identified six variables that could be used to develop a treatment prioritization. These variables include:

1. The total number of acres each invasive plant species inhabits,
2. The total number of population stands of each invasive plant species,
3. The quality of the habitat that the invasive plant species inhabits
4. NROC's habitat conservation priorities
5. Cal-IPC's managing concern ranking for each species (Cal-IPC 2006)
6. Proximity of invasive plants to road access points

Like most wildland areas in California, Coastal Orange County is infested with too many weed species to manage at once. Index ranking of invasive plants therefore provides a uniform methodology for control prioritization which allows for 1) the highest ranked and manageable species to be controlled first, 2) limited resources to be used efficiently, and 3) management decisions to be based on systematic rigor that are therefore defensible.

A series of index values ranging from 1 to 3 were developed for each prioritization variable. An index rank of 3 was assigned to variables that correlate with high priority treatment conditions such as; a small number and size of infestations, weeds infesting high quality or high priority habitat types, weed species that are of a particularly high management concern, and weed populations that are more easily accessible. An index ranking of 1 was designated for inverse conditions that correlate with low priority treatment conditions. These various index values were then compiled to develop an overall invasive plant priority ranking system discussed below.

Weed Acre Total Index

According to the concept expressed in the *Invasion Curve* (Figure 8), invasive species with small population size require less effort to control relative to larger and therefore more established populations. For this reason, invasive species infestations represented by "small" or incipient populations should be prioritized with a *Weed Acre Total Index* score of 3. Conversely, large and well-established weed population should be designated a *Weed Acre Total Index* score of 1.

To develop an index of "area size" of each infestation, the net invasive plant acreage total (GIS attribute data field entitled "*WeedAcres*") was tallied for each species. A frequency distribution

analysis was then conducted of the totals and a 95-percent confidence interval calculated (Figure 9). Those species with moderate population stand acreages that fell within the 95-percent confidence interval were assigned an index score of 2. Species with acreage values above and below the confidence interval were assigned index scores of 1 and 3 respectively.

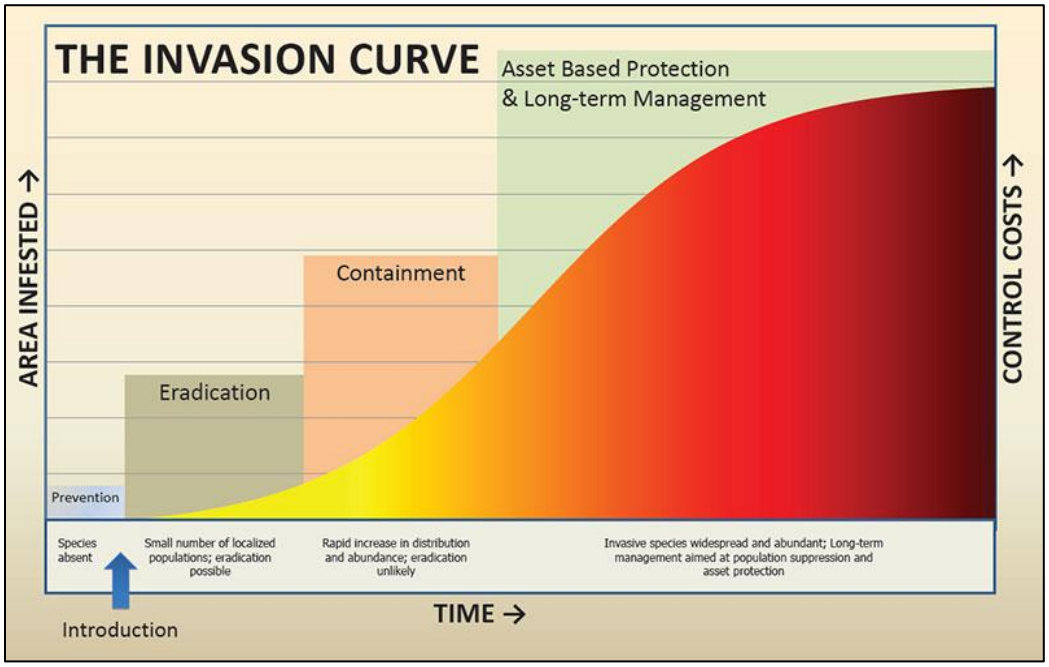

Figure 8. View of the classic *Invasion Curve* showing the relationship between weed infestation "size" and control costs. Photo courtesy of the North American Invasive Species Network (http://www.naisn.org).

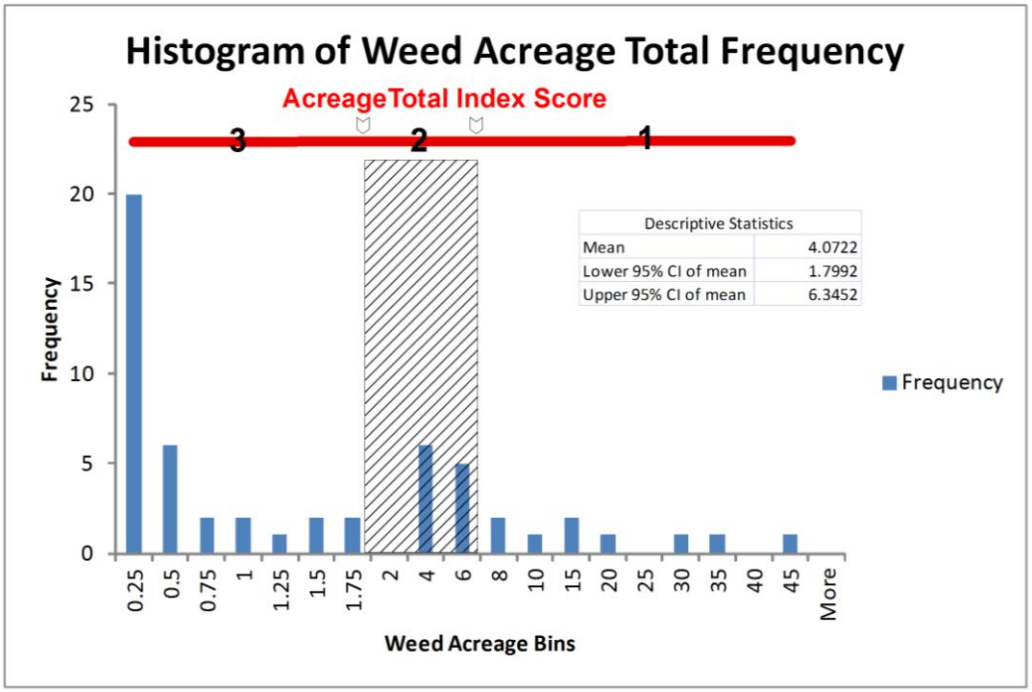

Figure 9. Frequency distribution of invasive plant species acreage totals with a 95% confidence interval used to determine the *Weed Acreage Index* score values (1-3).

Table 4. Summary of invasive plant population stand totals, weed acres and associated index values including infested habitat acres by species.

#	Species	Common Name	# of Stands	Stand Index	Total Weed Acres	Acre Index	Acres Infested Habitat
1	*Araujia sericifera*	Bladderflower			Not Found		
2	*Acacia cyclops*	Cyclops Acacia	87	1	6.90	1	91.68
3	*Agave americana*	Century Plant	9	3	0.10	3	0.31
4	*Ailanthus altissima*	Tree of Heaven			Not Found		
5	*Arundo donax*	Giant Reed	28	2	14.18	1	127.13
6	*Asphodelus fistulosus*	Onionweed	1	3	0.002	3	0.02
7	*Atriplex semibaccata*	Australian Saltbush	59	2	5.35	2	388.00
8	*Brassica sp.*	Unknown Mustard	1	3	0.0003	3	0.030
9	*Brassica tournefortii*	Sahara Mustard	1	3	0.02	3	0.07
10	*Buddleja davidii*	Butterflybush	1	3	0.004	3	0.004
11	*Cactoideae sp.*	Unknown Cactus	1	3	0.09	3	1.72
12	*Callistemon sp.*	Bottlebrush	2	3	0.16	3	15.54
13	*Carduus pycnocephalus*	Italian Thistle	56	2	31.63	1	308.30
14	*Carpobrotus edulis*	Iceplant	26	2	3.31	2	35.76
15	*Centaurea solstitialis*	Yellow Starthistle			Not Found		
16	*Cirsium vulgare*	Bull Thistle	5	3	0.05	3	0.44
17	*Conium maculatum*	Poison Hemlock	127	1	44.54	1	322.50
18	*Cortaderia selloana*	Pampas Grass	327	1	10.02	1	77.03
19	*Cynara cardunculus*	Artichoke Thistle	407	1	18.92	1	1127.81
20	*Cyperus papyrus*	Papyrus	4	3	0.04	3	3.36
21	*Echium candicans*	Pride of Madeira	27	2	3.32	3	27.94
22	*Ehrharta calycina*	Veldt grass			Not Found		
23	*Emex spinosa*	Spiny Emex			Not Found		
24	*Encelia farinosa*	Brittlebush	2	3	0.002	3	0.002
25	*Eucalyptus sp.*	Eucalyptus	42	2	26.86	1	50.78
26	*Foeniculum vulgare*	Fennel	168	1	4.39	2	195.42
27	*Gazania sp.*	Gazania	2	3	0.09	3	2.77
28	*Glebionis coronaria*	Garland Chrysanthemum	1	3	1.30	3	129.93
29	*Grass sp.*	Unknown Grass	6	3	4.29	2	9.03
30	*Hedera sp.*	Unknown Ivy	2	3	0.01	3	0.04
31	*Hypericum canariense*	Canary Island Saint John's Wort	1	3	0.02	3	0.09
32	*Lactuca serriola*	Wild Lettuce	6	3	0.03	3	1.69
33	*Lepidium latifolium*	Perennial Pepperweed	3	3	0.03	3	1.96
34	*Limonium ramosissimum*	Algerian Sea Lavender	4	3	2.12	2	211.92
35	*Limonium sinuatum*	Statice			Not Found		
36	*Marrubium vulgare*	Horehound	92	1	1.56	3	86.27
37	*Myoporum laetum*	Lollypop Tree	28	2	1.09	3	7.40
38	*Nerium oleander*	Oleander	3	3	0.04	3	0.56
39	*Nicotiana glauca*	Tree Tobacco	243	1	9.17	1	139.84
40	*Olea europaea*	Olive	7	3	0.31	3	0.35
41	*Opuntia ficus-indica*	Mission Cactus	6	3	0.28	3	23.29
42	*Paraserianthes lophantha*	Plume Acacia	3	3	0.52	3	7.70
43	*Pennisetum setaceum*	Fountain Grass	39	2	5.77	2	53.50
44	*Phalaris sp.*	Hardinggrass	3	3	4.37	2	87.46
45	*Philadelphus lewisii*	Mock Orange			Not Found		
46	*Phoenix canariensis*	Canary Island Date Palm	22	2	2.80	2	4.75
47	*Picris echioides*	Prickly Sowthistle	3	3	6.78	1	23.36
48	*Pinus sp.*	Unknown Pine Tree	16	3	2.78	2	5.59
49	*Piptatherum miliaceum*	Smilo Grass	20	2	0.24	3	4.85
50	*Ricinus communis*	Castor Bean	26	2	1.70	3	3.31
51	*Robinia pseudoacacia*	Black Locust	4	3	0.85	3	4.29
52	*Schinus molle*	Peruvian Pepper Tree	41	2	3.67	2	16.96
53	*Schinus terebinthifolius*	Brazilian Pepper Tree	13	3	0.54	3	2.92
54	*Silybum marianum*	Milk Thistle	12	3	1.32	3	6.45
55	*Spartium junceum*	Spanish Broom			Not Found		
56	*Stipa trichotoma*	Mexican Feather Grass	12	3	0.03	3	0.59
57	*Tamarix sp.*	Tamarisk	37	2	0.42	3	1.82
58	*Tragopogon porrifolius*	Salsify			Not Found		
59	*Tree sp.*	Unknown Tree	12	3	0.25	3	4.62
60	*Tropaeolum majus*	Garden Nasturtium	5	3	0.45	3	1.76
61	*Ulmus parvifolia*	Chinese Elm	16	3	0.25	3	1.41
62	*Washingtonia robusta*	Mexican Fan Palm	63	1	0.89	3	41.02
63	*Yucca sp.*	Unknown Yucca	1	3	0.001	3	0.001

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Weed Stand Total Index

As discussed in the section above and shown in Figure 8, eradication is most effective and less costly when the total number of weed population stands is low. The number of populations a species has is an indicator of the access time needed to eradicate that species. Traveling to many populations is much more time consuming and difficult than accessing one or few populations. The number of populations is also an effective way to determine which phase of invasion a species is in or how invasive it is, i.e. many small populations could mean the species is in an expansion phase of invasion. Typically, smaller populations have less seed in the soil, and are thus easier to eradicate. Therefore, a higher priority (*Weed Stand Total Index* score of 3) was assigned to those weed species with the lowest number of population stand occurrences and an index score of 1 to those species with the most numerous stand totals.

To develop the *Weed Stand Total Index*, the invasive plant population stand total was tallied for each species. A frequency distribution analysis was then conducted of the totals and a 95 percent confidence interval was calculated to determine the *Weed Stand Total Index* score from 1-3 (low-high priority; Figures 9 & 10).

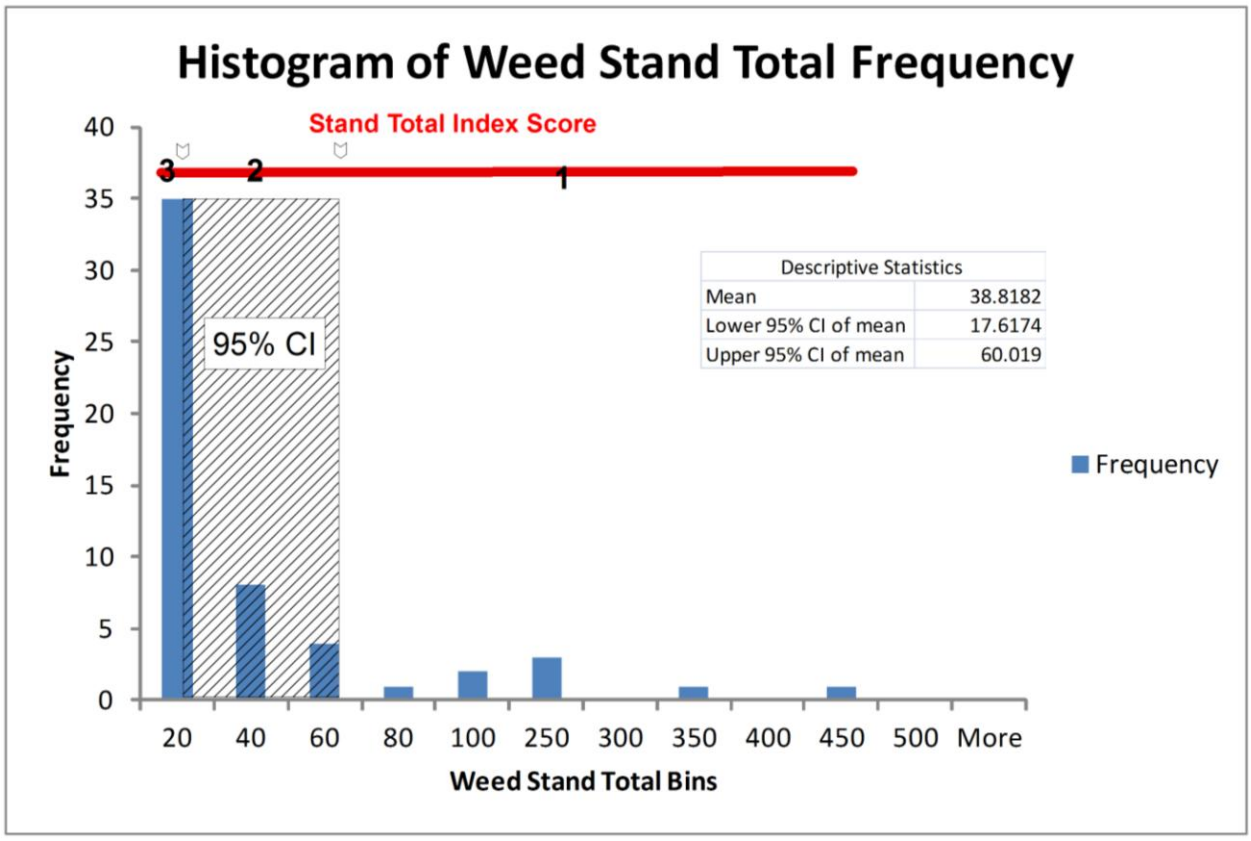

Figure 10. Frequency distribution of invasive plant species population stand totals with a 95% confidence interval used to determine the *Weed Stand Total Index* score values (1-3).

Habitat Quality Index

In 2014, the NROC developed a comprehensive GIS map of all NCCP regions identifying the distribution of various vegetation classification units using the *Manual of California Vegetation* (MCV) developed by the California Department of Fish and Wildlife Vegetation Classification and Mapping Program (CDFW) in collaboration with the California Native Plant Society (CNPS; Sawyer et al. 2009, NROC in prep). In addition to basic vegetation information, additional habitat metrics including land-use type, degree of "exoticness" (relative cover of non-native plant species including non-native grasses) and the degree of habitat disturbance was geospatially documented. To develop the *Habitat Quality Index*, WCS made use of these three assessed variables. A binomial index value was assigned to each range of habitat condition variables. Habitat variable rankings indicating high-quality habitat conditions received an index value of 1 while those variables indicating moderate to low quality conditions received an index value of 0 (Table 5).

WCS then performed an intersect analysis function using GIS software which functionally cut the geospatial weed map into small pieces based on the extent of habitat polygons present in the *VegPoly* shapefile. The remaining product is an appended map showing the location and attribute information of the weed map along with the underlying habitat map with associated attribute information. For example, a single weed feature that straddles two habitat types would be cut in half along the habitat transition line and then appended with the additional habitat information. The result of this analysis is a more detailed map that links weed information to its underlying habitat type. For the purposes of developing an index, these refined multi-data features will be referred to herein as "stand/habitat patches".

An additive ranking matrix was then calculated for each stand/habitat patch which produced a *Habitat Quality Ranking* (scored 1-3; low to high quality habitat) for each feature (Equation 1).

Equation 1. Method of calculating the habitat quality ranking of each stand/habitat "patch".

$$\boldsymbol{HQR} = (d + e + l)$$

HQR*=Stand/habitat patch ranking habitat quality ranking*
d= Stand/habitat patch ranking of Vegpoly Disturbance Ranking Index
e = Stand/habitat patch ranking of VegPoly Exotic Ranking Index
l= Stand/habitat patch ranking of VegPoly Land Use Ranking Index

The overall *Habitat Quality Index* for each species was calculated using the relative frequency of stand/habitat patches with various *Habitat Quality Ranking* scores (Equation 2). Table 6 provides a *Habitat Quality Index* of all invasive plants detected within the NCCP's Coastal Subregion. A species index score of 3 indicates that most of the population stands occur in areas of good quality habitat whereas a score of 1 indicates that most stands occur in poorer habitat quality.

Equation 2. Method of calculating *Habitat Quality Index* of each invasive plant species.

$$\boldsymbol{HQI} = \left[\left(\frac{HQR\_1}{t} \times 1\right) + \left(\frac{HQR\_2}{t} \times 2\right) + \left(\frac{HQR\_3}{t} \times 3\right)\right]$$

HQI= Habitat quality index by species
HQR_x= Number of stand/habitat patches with a Habitat Quality Ranking of x (x=1, 2 or 3)
t = Total number of stand/habitat patches

Table 5. Habitat cover value ranges developed during the previous GIS habitat condition and vegetation classification project and the associated binomial index value assigned to various ranges by WCS.

VegPoly Codes and Cover Values	VegPoly Ranking Index Values
VegPoly Disturbance Modifier	**VegPoly Disturbance Index**
0= None	**1**
1= Low (<33% of poly affected)	
2= Medium (33-66% of poly affected)	**0**
3= High (>66% of poly affected)	
9= Not applicable/Not applied	

VegPoly Exotic Component Modifier	VegPoly Exotic Index
0= None	**1**
1=Low/minor	
2= Moderate	**0**
3= High	
9= Not applicable/Not applied	

VegPoly Land Use Codes	VegPoly Land Use Index
0= No Land Use	**1**
9800= Undifferentiated Water	
1000= Urban	**0**
1800= Special Linkage	
2000= Agriculture	
9= Not evaluated	

Table 6. Summary of *Habitat Quality Index* scores for each invasive plant species based on the associated land use, "exoticness", and disturbance level of the habitat that the weed has infested.

Species	Common Name	Habitat Quality Index	Species	Common Name	Habitat Quality Index
Araujia sericifera	Bladderflower	NA	*Lepidium latifolium*	Perennial Pepperweed	1.00
Acacia cyclops	Cyclops Acacia	2.64	*Limonium ramosissimum*	Algerian Sea Lavender	1.53
Agave americana	Century Plant	2.64	*Limonium sinuatum*	Statice	NA
Ailanthus altissima	Tree of Heaven	NA	*Marrubium vulgare*	Horehound	2.49
Arundo donax	Giant Reed	2.75	*Myoporum laetum*	Lollypop Tree	2.72
Asphodelus fistulosus	Onionweed	1.00	*Nerium oleander*	Oleander	2.00
Atriplex semibaccata	Australian Saltbush	2.12	*Nicotiana glauca*	Tree Tobacco	2.72
Brassica sp.	Unknown Mustard	1.00	*Olea europaea*	Olive	2.71
Brassica tournefortii	Sahara Mustard	2.00	*Opuntia ficus-indica*	Mission Cactus	2.57
Buddleja davidii	Butterflybush	2.00	*Paraserianthes lophantha*	Plume Acacia	2.85
Cactoideae sp.	Unknown Cactus	3.00	*Pennisetum setaceum*	Fountain Grass	2.64
Callistemon sp.	Bottlebrush	2.73	*Phalaris sp.*	Hardinggrass	2.81
Carduus pycnocephalus	Italian Thistle	2.75	*Philadelphus lewisii*	Mock Orange	NA
Carpobrotus edulis	Iceplant	2.66	*Phoenix canariensis*	Canary Island Date Palm	2.76
Centaurea solstitialis	Yellow Starthistle	NA	*Picris echioides*	Prickly Sowthistle	2.14
Cirsium vulgare	Bull Thistle	2.25	*Pinus sp.*	Unknown Pine Tree	2.84
Conium maculatum	Poison Hemlock	2.69	*Piptatherum miliaceum*	Smilo Grass	2.75
Cortaderia selloana	Pampas Grass	2.88	*Ricinus communis*	Castor Bean	2.36
Cynara cardunculus	Artichoke Thistle	2.55	*Robinia pseudoacacia*	Black Locust	2.49
Cyperus papyrus	Papyrus	2.80	*Schinus molle*	Peruvian Pepper Tree	2.56
Echium candicans	Pride of Madeira	2.91	*Schinus terebinthifolius*	Brazilian Pepper Tree	2.73
Ehrharta calycina	Veldt grass	NA	*Silybum marianum*	Milk Thistle	2.47
Emex spinosa	Spiny Emex	NA	*Spartium junceum*	Spanish Broom	NA
Encelia farinosa	Brittlebush	2.00	*Stipa trichotoma*	Mexican Feather Grass	2.11
Eucalyptus sp.	Eucalyptus	2.63	*Tamarix sp.*	Tamarisk	2.46
Foeniculum vulgare	Fennel	2.54	*Tragopogon porrifolius*	Salsify	NA
Gazania sp.	Gazania	2.85	*Tree sp.*	Unknown Tree	2.83
Glebionis coronaria	Garland Chrysanthemum	1.13	*Tropaeolum majus*	Garden Nasturtium	2.51
Grass sp.	Unknown Grass	2.19	*Ulmus parvifolia*	Chinese Elm	2.67
Hedera sp.	Unknown Ivy	2.82	*Washingtonia robusta*	Mexican Fan Palm	2.85
Hypericum canariense	Canary Island Saint John's Wort	3.00	*Yucca sp.*	Unknown Yucca	3.00
Lactuca serriola	Wild Lettuce	2.13			

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Habitat Priority Index

As mentioned above, the NROC developed a comprehensive GIS vegetation classification map of all NCCP regions using the MCV mapping classification protocol (NROC in prep). WCS used this geospatial data to identify the types of habitat that each invasive plant population stand was infesting using the GIS intercept analysis methodology described above.

WCS then reviewed the list of vegetation classification units represented in the "stand/habitat patches" and grouped them into larger more coarsely defined habitat types. This list was then shared with NROC coordinators Dr. Milan Mitrovich and Dr. Jutta Burger, who were asked to assign *Priority Rankings* (scored 1-3; low to high priority) for each habitat type based on the NROC's coastal resource conservation priority and management objectives (Table 7). Figure 11 provides a summary of total acres of weed infestation that occurs within the various habitat types ranked in Table 7. Figure 12 provides a similar illustration of each invasive plant species documented in the NCCP's Coastal Subregion sorted by acres of habitat infested and each *Habitat Priority Ranking* value.

Equation 3. Method of calculating the *Habitat Priority Index* for each invasive plant species.

$$\boldsymbol{HPI} = \left[\left(\frac{HPR\_1}{t} \times 1\right) + \left(\frac{HPR\_2}{t} \times 2\right) + \left(\frac{HPR\_3}{t} \times 3\right)\right]$$

HPI= Habitat priority index by species
HPR_x= Number of stand/habitat patches with a Habitat Prioritization Ranking of x (x=1, 2 or 3)
t = Total number of stand/habitat patches

The overall *Habitat Priority Index* for each species was calculated using the relative frequency of stand/habitat patches with various *Habitat Priority Ranking* scores (Equation 3). Table 8 provides a *Habitat Quality Index* of all invasive plants detected within the NCCP's Coastal Subregion. A species index score of 3 indicates that most of the population stands occur in areas of high priority habitat whereas a score of 1 indicates that most stands occur in low priority habitat.

Table 7. Table of vegetation classification types (alliances, associations and semi-natural types) grouped into coarsely related habitat groupings. Each habitat was priority ranked (1-3) based on preservation and management considerations.

VegName_"Habitat"	VegPoly_VegName Classification	NROC Habitat Ranking Prioritizaton Ranking Index 1-3
Agriculture	Agriculture	1
Coastal Sage Scrub	*Artemisia californica* - *Eriogonum fasciculatu* m Alliance *Artemisia californica* - *Salvia mellifera* Alliance *Artemisia californica* Alliance *Baccharis pilularis* Alliance Central & South Coastal Californian CSS Group Central and South Coastal Californian seral scrub Gp *Encelia californica* Alliance *Eriogonum fasciculatum* Alliance *Isocoma menziesii* Alliance *Mimulus aurantiacus* Alliance *Salvia mellifera* Alliance	3
Fuel Mod Zone	Fuel Mod Zone	1
Live Oak Woodland	*Quercus agrifolia* Alliance	3
Maritime Chaparral	Californian maritime chaparral Gp *Malosma laurina* Alliance *Rhus integrifolia* Alliance	3
Mesic Coastal Sage Scrub	*Toxicodendron diversilobum* Alliance	3
Native Dominated Riparian	*Baccharis salicifolia* Alliance *Platanus racemosa* Alliance *Populus fremontii* Alliance *Salix goodingii* Alliance *Salix laevigata* Alliance *Salix lasiolepis* Alliance *Sambucus nigra* Alliance Streambed Mapping Unit SW N. Amer. Rip. evergreen and decid. woodland Gp SW North American riparian/wash scrub Gp	3
Native Grassland	*Nassella pulchra* Alliance	3
Non-native Dominated Riparian	*Arundo donax* Alliance	3
Non-native Dominated Upland	*Acacia* (*Cyclops*) Semi-Natural Stands Alliance *Brassica nigra* and other mustards Alliance *Cynara cardunculus* Provisional Semi-Natural Stands Alliance *Eucalyptus* (*globulus, camaldulensis*) Semi-Natural Stands Alliance Introduced Trees, Shrubs (not in hierarchy)	1
Non-native Grassland	*Bromus* (*diandrus, hordeaceus*) - *Brachypodium distachyon* Alliance California Annual and Perennial Grassland MG Mediterranean CA Naturalized Annual and Perennial Grassland Group (Weedy)	2
Sparsely Vegetated	Cliff, bluffs, scree, and rock outcrop Sparsely vegetated to non-vegetated	2
Urban/Anthropogenic	Anthropogenic Areas of Little or No Vegetation Urban/disturbed Mapping Unit	1
Wetland/Waterbody	Ephemeral ponds & reservoirs Fresh water marsh (bulrush - cattail) MU *Schoenoplectus acutus* Alliance Temperate and Boreal Freshwater Marsh Fm *Typha* (*angustifolia, domingensis, latifolia*) Alliance Water body	3
Maritime Succulent Scrub	Opuntia littoralis Alliance	3
Golf Course	Special Linkage Area	1
Salt Basin/ High Marsh	*Atriplex lentiformis* Alliance	3
Xeric Chaparral	*Adenostoma fasciculatum* Alliance *Ceanothus megacarpus* Alliance *Querecus dumosa* Alliance	2
Mesic Chaparral	*Heteromeles arbutifolia* Alliance *Quercus berberidifolia* Alliance	2

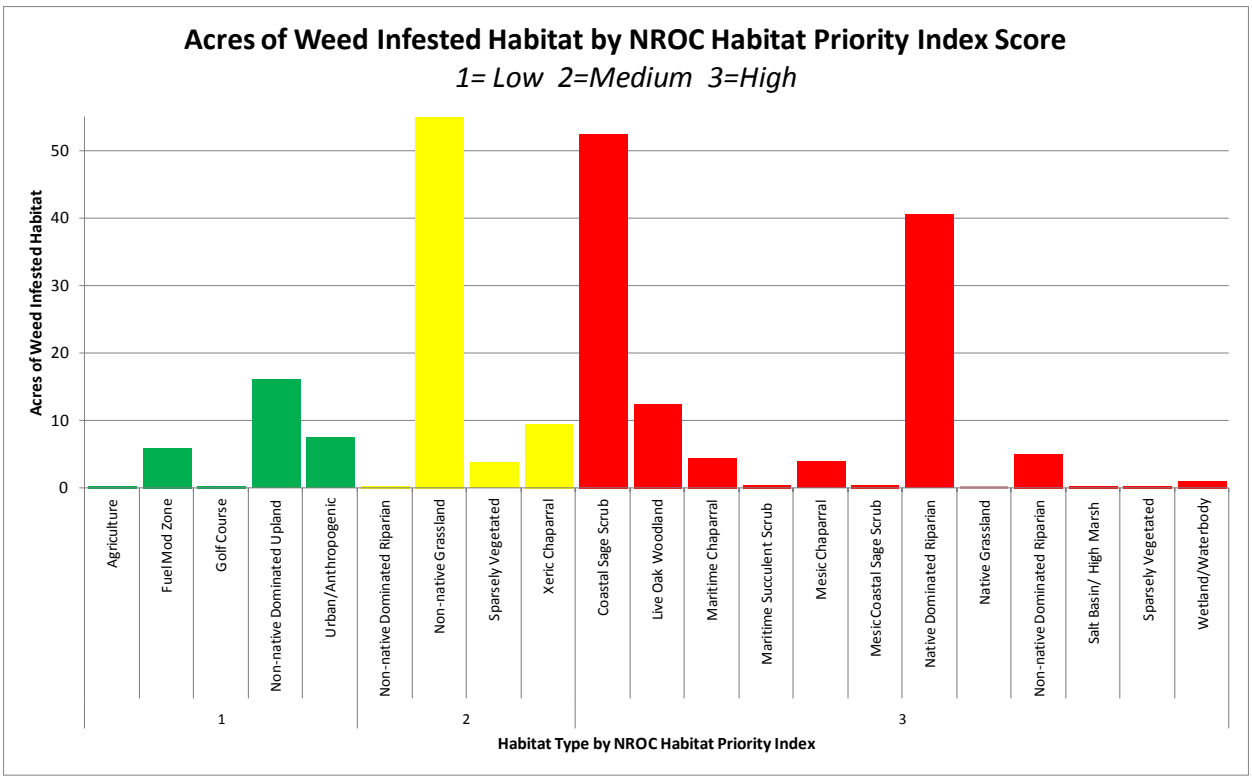

Figure 11. Total acres of infested habitat and *Habitat Priority Index* score.

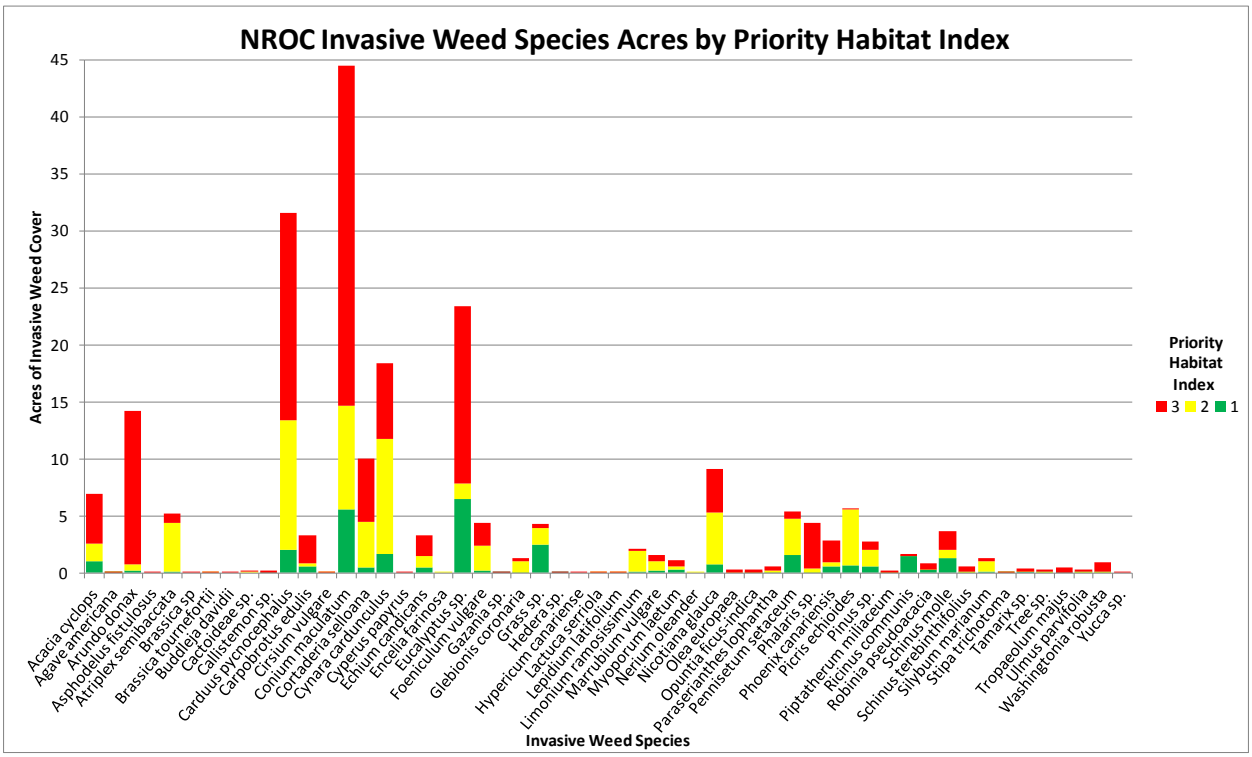

Figure 12. Total acres of each invasive species by the *Habitat Priority Index* score of the habitats that were infested by that species.

Table 8. Summary of *Habitat Priority Index* scores for each invasive plant species based on the NROC's coastal resource conservation priorities and management objectives for each habitat type.

Species	Common Name	Habitat Quality Index	Species	Common Name	Habitat Quality Index
Araujia sericifera	Bladderflower	NA	*Lepidium latifolium*	Perennial Pepperweed	2.91
Acacia cyclops	Cyclops Acacia	2.47	*Limonium ramosissimum*	Algerian Sea Lavender	2.04
Agave americana	Century Plant	1.96	*Limonium sinuatum*	Statice	NA
Ailanthus altissima	Tree of Heaven	NA	*Marrubium vulgare*	Horehound	2.22
Arundo donax	Giant Reed	2.93	*Myoporum laetum*	Lollypop Tree	2.25
Asphodelus fistulosus	Onionweed	3.00	*Nerium oleander*	Oleander	2.00
Atriplex semibaccata	Australian Saltbush	2.14	*Nicotiana glauca*	Tree Tobacco	2.33
Brassica sp.	Unknown Mustard	3.00	*Olea europaea*	Olive	2.95
Brassica tournefortii	Sahara Mustard	2.17	*Opuntia ficus-indica*	Mission Cactus	2.69
Buddleja davidii	Butterflybush	3.00	*Paraserianthes lophantha*	Plume Acacia	2.60
Cactoideae sp.	Unknown Cactus	2.26	*Pennisetum setaceum*	Fountain Grass	1.82
Callistemon sp.	Bottlebrush	2.97	*Phalaris sp.*	Hardinggrass	2.90
Carduus pycnocephalus	Italian Thistle	2.51	*Philadelphus lewisii*	Mock Orange	NA
Carpobrotus edulis	Iceplant	2.60	*Phoenix canariensis*	Canary Island Date Palm	2.47
Centaurea solstitialis	Yellow Starthistle	NA	*Picris echioides*	Prickly Sowthistle	1.89
Cirsium vulgare	Bull Thistle	2.98	*Pinus sp.*	Unknown Pine Tree	2.07
Conium maculatum	Poison Hemlock	2.55	*Piptatherum miliaceum*	Smilo Grass	2.86
Cortaderia selloana	Pampas Grass	2.51	*Ricinus communis*	Castor Bean	1.22
Cynara cardunculus	Artichoke Thistle	2.27	*Robinia pseudoacacia*	Black Locust	2.31
Cyperus papyrus	Papyrus	3.00	*Schinus molle*	Peruvian Pepper Tree	2.10
Echium candicans	Pride of Madeira	2.40	*Schinus terebinthifolius*	Brazilian Pepper Tree	2.76
Ehrharta calycina	Veldt grass	NA	*Silybum marianum*	Milk Thistle	2.21
Emex spinosa	Spiny Emex	NA	*Spartium junceum*	Spanish Broom	NA
Encelia farinosa	Brittlebush	2.00	*Stipa trichotoma*	Mexican Feather Grass	1.35
Eucalyptus sp.	Eucalyptus	2.39	*Tamarix sp.*	Tamarisk	2.56
Foeniculum vulgare	Fennel	2.40	*Tragopogon porrifolius*	Salsify	NA
Gazania sp.	Gazania	1.09	*Tree sp.*	Unknown Tree	2.68
Glebionis coronaria	Garland Chrysanthemum	2.20	*Tropaeolum majus*	Garden Nasturtium	2.98
Grass sp.	Unknown Grass	1.52	*Ulmus parvifolia*	Chinese Elm	2.33
Hedera sp.	Unknown Ivy	3.00	*Washingtonia robusta*	Mexican Fan Palm	2.92
Hypericum canariense	Canary Island Saint John's Wort	3.00	*Yucca sp.*	Unknown Yucca	3.00
Lactuca serriola	Wild Lettuce	2.02			

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Cal-IPC Ranking Index

The California Invasive Plant Council's (Cal-IPC) Invasive Plant Inventory was used to determine the threat posed by each species across the state (Cal-IPC 2006). The Inventory was developed by individually ranking each species using a plant assessment form (PAF), which is separated into three subject sections that are composed of several sub-sections listed below:

Section 1- Ecological Impact
- 1.1- Impact on abiotic ecosystem processes
- 1.2- Impact on plant community composition, structure, and interactions
- 1.3- Impact on higher trophic levels
- 1.4- Impact on genetic integrity

Section 2- Invasive Potential
- 2.1- Role of anthropogenic and natural disturbance in establishment
- 2.2- Local rate of spread with no management
- 2.3- Recent trend in total area infested within California
- 2.4- Innate reproductive potential
- 2.5- Potential for human-caused dispersal
- 2.6- Potential for natural long-distance dispersal (>1 km)
- 2.7- Other regions invaded

Section 3- Ecological Amplitude and Distribution

3.1- Ecological amplitude

3.2- Distribution

Cal-IPC developed a matrix ranking system to compile and balance data gathered for each weed species for all section scores to determine the species' overall score and rank. Ranking categories are as follows:

> **High**: These species have severe ecological impacts on ecosystems, plant and animal communities, and vegetation structure. Their reproductive biology and other attributes are conducive to moderate to high rates of dispersal and establishment. These species are usually widely distributed ecologically, both among and within ecosystems.
>
> **Moderate**: These species have substantial and apparent but generally not severe ecological impacts on ecosystems, plant and animal communities, and vegetation structure. Their reproductive biology is conducive to moderate to high rates of dispersal, though establishment is generally dependent on ecological disturbance. Ecological amplitude and distribution may range from limited to widespread.
>
> **Limited**: The ecological impacts of these species are minor. Their reproductive biology and other invasiveness attributes result in low to moderate rates of invasion. Ecological amplitude and distribution tend to be generally limited (however, they may be locally persistent and problematic). These species may be more problematic than their rank reveals if there is a lack of published literature.

WCS incorporated the Cal-IPC Inventory ranking for each species whenever available. High, moderate and limited ranked species were designated *Cal-IPC Ranking Index* scores of 3-1 respectively (Table 9). Though the majority of invasive plants on NCCP's Coastal Region were included in the Cal-IPC Inventory and possessed ranking score values, 21 invasive plant species (including some higher taxonomic classifications) have not been assessed or ranked by Cal-IPC (Table 8). For those species, the *Cal-IPC Ranking Index* was inferred by WCS based on general knowledge of the invasive plant in Southern and Central California and observations of the infestations within the NCCP sub-region. Prior to use of these proposed index values in the prioritization, they were submitted for concurrence with Dr. Jutta Burger.

Table 9. Summary of *Cal-IPC Ranking Index* scores for each invasive plant species based on each species' impacts, invasiveness, and range and frequency of habitat types invaded throughout California.

Species	Common Name	CAL-IPC Ranking Index	Species	Common Name	CAL-IPC Ranking Index
Araujia sericifera	Bladderflower	NA	*Lepidium latifolium*	Perennial Pepperweed	3.00
Acacia cyclops	Cyclops Acacia	2.00	*Limonium ramosissimum*	Algerian Sea Lavender	1.00
Agave americana	Century Plant	1.00	*Limonium sinuatum*	Statice	NA
Ailanthus altissima	Tree of Heaven	NA	*Marrubium vulgare*	Horehound	1.00
Arundo donax	Giant Reed	3.00	*Myoporum laetum*	Lollypop Tree	2.00
Asphodelus fistulosus	Onionweed	2.00	*Nerium oleander*	Oleander	1.00
Atriplex semibaccata	Australian Saltbush	2.00	*Nicotiana glauca*	Tree Tobacco	2.00
Brassica sp.	Unknown Mustard	1.00	*Olea europaea*	Olive	1.00
Brassica tournefortii	Sahara Mustard	3.00	*Opuntia ficus-indica*	Mission Cactus	1.00
Buddleja davidii	Butterflybush	1.00	*Paraserianthes lophantha*	Plume Acacia	1.00
Cactoideae sp.	Unknown Cactus	1.00	*Pennisetum setaceum*	Fountain Grass	2.00
Callistemon sp.	Bottlebrush	1.00	*Phalaris sp.*	Hardinggrass	2.00
Carduus pycnocephalus	Italian Thistle	2.00	*Philadelphus lewisii*	Mock Orange	NA
Carpobrotus edulis	Iceplant	3.00	*Phoenix canariensis*	Canary Island Date Palm	1.00
Centaurea solstitialis	Yellow Starthistle	NA	*Picris echioides*	Prickly Sowthistle	1.00
Cirsium vulgare	Bull Thistle	2.00	*Pinus sp.*	Unknown Pine Tree	1.00
Conium maculatum	Poison Hemlock	2.00	*Piptatherum miliaceum*	Smilo Grass	1.00
Cortaderia selloana	Pampas Grass	3.00	*Ricinus communis*	Castor Bean	1.00
Cynara cardunculus	Artichoke Thistle	2.00	*Robinia pseudoacacia*	Black Locust	1.00
Cyperus papyrus	Papyrus	1.00	*Schinus molle*	Peruvian Pepper Tree	1.00
Echium candicans	Pride of Madeira	1.00	*Schinus terebinthifolius*	Brazilian Pepper Tree	1.00
Ehrharta calycina	Veldt grass	NA	*Silybum marianum*	Milk Thistle	1.00
Emex spinosa	Spiny Emex	NA	*Spartium junceum*	Spanish Broom	NA
Encelia farinosa	Brittlebush	1.00	*Stipa trichotoma*	Mexican Feather Grass	2.00
Eucalyptus sp.	Eucalyptus	2.00	*Tamarix sp.*	Tamarisk	3.00
Foeniculum vulgare	Fennel	3.00	*Tragopogon porrifolius*	Salsify	NA
Gazania sp.	Gazania	1.00	*Tree sp.*	Unknown Tree	1.00
Glebionis coronaria	Garland Chrysanthemum	2.00	*Tropaeolum majus*	Garden Nasturtium	1.00
Grass sp.	Unknown Grass	1.00	*Ulmus parvifolia*	Chinese Elm	1.00
Hedera sp.	Unknown Ivy	2.00	*Washingtonia robusta*	Mexican Fan Palm	2.00
Hypericum canariense	Canary Island Saint John's Wort	2.00	*Yucca sp.*	Unknown Yucca	1.00
Lactuca serriola	Wild Lettuce	2.00			

BLACK TEXT= Species listed in the Statement of Work DETECTED during the surveys
TURQUOISE TEXT= Species listed in the Statement of Work NOT DETECTED during the surveys
GREEN TEXT= Species or taxa NOT LISTED in the Statement of Work but detected during the surveys
PINK NUMBER= Species or taxa not assessed by CAL-IPC. Value ranking score inferred based on WCS observations in the field

Weed Distance Index

To maximize treatment efficiency and minimize cost, those invasive species that are easily accessible should be given priority over similar invasive species occurring within the same quality habitat. To develop the *Weed Distance Index*, a nearness analysis was conducted using GIS software that measured the distance of all invasive plant population stands to the nearest roadway access. It should be noted that this linear foot measurement does not take into account topography, private property limitations, and impenetrable vegetation. It is therefore not an all-inclusive assessment of access. However, it does provide a good general indication of how accessible any particular population stand is.

Road distance measurements were then grouped into three *Distance Ranking Values* based on practical access to the weed using various types of treatment equipment. A *Distance Ranking Value* of 3 was assigned to those population stands with a road distance <100 feet indicating the stand would be easily accessed by nearly any kind of weed treatment equipment. A *Distance Ranking Value* of 2 was assigned to those stands from 100 to 600 feet from a road. This range is reachable with both backpack and hose mounted skid spray equipment. A *Distance Ranking Value* of 1 was assigned to those stands >600 feet from a road because these population stands are only accessible on foot or using a helicopter for easy access (Table 10).

Table 10. Index ranking thresholds designated for each invasive plant population stand based on distance to a road access point.

Stand Distance Road (Ft)	Ranking Values
0 to 100 feet	**3**
100 to 600 feet	**2**
600+ feet	**1**

The overall *Road Distance Index* for each species was calculated using the relative frequency of population stands with various *Distance Ranking Value* scores (Equation 4). Table 10 provides *Road Distance Index* of all invasive plants detected within the NCCP's Coastal Subregion. A *Road Distance Index* score of 3 indicates that most of the population stands occur close to a road access point, whereas a score of 1 indicates that most stands occur farther away.

Equation 4. Method of calculating the *Road Distance Index* of each invasive plant species.

$$\boldsymbol{RDI} = \left[\left(\frac{RDI\_1}{t} \times 1\right) + \left(\frac{RDI\_2}{t} \times 2\right) + \left(\frac{HPR\_3}{t} \times 3\right)\right]$$

RDI*= Road distance index by species*
RDR_X= Total number of stand/habitat patches with a Habitat Prioritization Ranking of X (X=1, 2 or 3)
t = Total number of stand/habitat patches

Table 11. Summary of *Road Distance Index* scores for each invasive plant species based on the average distance of each population stand's distance to a road access point.

Species	Common Name	Road Distance Index	Species	Common Name	Road Distance Index
Araujia sericifera	Bladderflower	NA	*Lepidium latifolium*	Perennial Pepperweed	1.67
Acacia cyclops	Cyclops Acacia	2.03	*Limonium ramosissimum*	Algerian Sea Lavender	1.50
Agave americana	Century Plant	2.11	*Limonium sinuatum*	Statice	NA
Ailanthus altissima	Tree of Heaven	NA	*Marrubium vulgare*	Horehound	2.04
Arundo donax	Giant Reed	1.46	*Myoporum laetum*	Lollypop Tree	1.93
Asphodelus fistulosus	Onionweed	2.00	*Nerium oleander*	Oleander	1.67
Atriplex semibaccata	Australian Saltbush	1.80	*Nicotiana glauca*	Tree Tobacco	2.09
Brassica sp.	Unknown Mustard	1.00	*Olea europaea*	Olive	2.71
Brassica tournefortii	Sahara Mustard	2.00	*Opuntia ficus-indica*	Mission Cactus	2.00
Buddleja davidii	Butterflybush	2.00	*Paraserianthes lophantha*	Plume Acacia	1.67
Cactoideae sp.	Unknown Cactus	2.00	*Pennisetum setaceum*	Fountain Grass	1.56
Callistemon sp.	Bottlebrush	1.50	*Phalaris sp.*	Hardinggrass	1.67
Carduus pycnocephalus	Italian Thistle	1.66	*Philadelphus lewisii*	Mock Orange	NA
Carpobrotus edulis	Iceplant	1.65	*Phoenix canariensis*	Canary Island Date Palm	1.82
Centaurea solstitialis	Yellow Starthistle	NA	*Picris echioides*	Prickly Sowthistle	1.67
Cirsium vulgare	Bull Thistle	1.60	*Pinus sp.*	Unknown Pine Tree	1.94
Conium maculatum	Poison Hemlock	1.72	*Piptatherum miliaceum*	Smilo Grass	1.20
Cortaderia selloana	Pampas Grass	2.21	*Ricinus communis*	Castor Bean	1.73
Cynara cardunculus	Artichoke Thistle	1.93	*Robinia pseudoacacia*	Black Locust	1.00
Cyperus papyrus	Papyrus	2.00	*Schinus molle*	Peruvian Pepper Tree	1.59
Echium candicans	Pride of Madeira	1.96	*Schinus terebinthifolius*	Brazilian Pepper Tree	1.54
Ehrharta calycina	Veldt grass	NA	*Silybum marianum*	Milk Thistle	2.17
Emex spinosa	Spiny Emex	NA	*Spartium junceum*	Spanish Broom	NA
Encelia farinosa	Brittlebush	2.50	*Stipa trichotoma*	Mexican Feather Grass	1.17
Eucalyptus sp.	Eucalyptus	1.50	*Tamarix sp.*	Tamarisk	2.05
Foeniculum vulgare	Fennel	1.72	*Tragopogon porrifolius*	Salsify	NA
Gazania sp.	Gazania	1.00	*Tree sp.*	Unknown Tree	1.83
Glebionis coronaria	Garland Chrysanthemum	1.00	*Tropaeolum majus*	Garden Nasturtium	1.20
Grass sp.	Unknown Grass	1.67	*Ulmus parvifolia*	Chinese Elm	1.00
Hedera sp.	Unknown Ivy	1.50	*Washingtonia robusta*	Mexican Fan Palm	1.71
Hypericum canariense	Canary Island Saint John's Wort	2.00	*Yucca sp.*	Unknown Yucca	1.00
Lactuca serriola	Wild Lettuce	1.83			

BLACK TEXT= Species listed in the Statement of Work DETECTED during the surveys
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4.2 NROC Invasive Plant Prioritization Ranking

Due to limited resources available for land stewardship, it is necessary to prioritize management objectives. For this reason, a systematic and transparent prioritization of objectives is necessary. Having developed the six descriptive indices (ranked 1-3, low to high priority for control) discussed above, the objective of this project is to develop a quantitative invasive plant treatment prioritization ranking system.

The first and perhaps most logical way of utilizing these indices is to sum the index scores for each invasive plant species. This *Additive Priority Score* will result in a single value that identifies those species that are best suited for treatment due to their particularly small population and infestation area, occurrence in high quality and high priority habitats, ecological "impactfulness" and invasiveness within natural systems, and distance to access points (Equation 5; Table 12; Figure 13).

Equation 5. Method of calculating the *Additive Priority Score* for each invasive plant species.

$$\boldsymbol{APS} = ATI + STI + HQI + HPI + CRI + RDI$$

APS*= Additive priority score for a species*
ATI= Acre total index
RDI= Stand total index
HQI= Habitat quality index
HPI= Habitat priority index
CRI= CAL-IPC ranking index
RDI= Road distance index

While an additive priority system is effective, not all index factors represent topics that are of equal importance to land managers. After a detailed review of various quantitative prioritization options, WCS devised a modified additive priority system that allows particular indices to be given additional weight relative to others. This *Weighed Priority Score* was submitted to NROC coordinators Dr. Milan Mitrovich and Dr. Jutta Burger for review to determine which indices may deserve additional consideration. After review of the ranking system, it was determined that the *Cal-IPC Ranking Index* should be weighted by a multiplication factor of 2. This newly weighted prioritization score stresses ecological "impactfulness", invasiveness and regional saturation of each species relative to the other indices within the ranking system (Equation 6; Table 12; Figure 13).

Equation 6. Method of calculating the *Weighed Priority Score* for each invasive plant species.

$$\boldsymbol{WPS} = (ATI \times w1) + (STI \times w2) + (HQI \times w3) + (HPI \times w4) + (CRI \times w5) + (RDI \times w6)$$

WPS*= Weighed priority score for a species*
ATI= Acre total index
RDI= Stand total index
HQI= Habitat quality index
HPI= Habitat priority index
CRI= CAL-IPC ranking index
RDI= Road distance index
w(#)=weighing factor by index

Table 12. Summary of the six varible index scores for each invasive plant species with calculated *Additive* and *Weighed Priority Scores* sorted from high to low ranking by the *Weighed Priority Score Index.*

Species	Common Name	Acre Total Index Weighting Factor	Acre Total Index	Stand Total Index Weighting Factor	Stand Total Index	Habitat Quality Index Weighting Factor	Habitat Quality Index	Habitat Priority Index Weighting Factor	Habitat Priority Index	CAL_IPC Rank Index Weighting Factor	CAL-IPC Rank Index	Distance Index Weighting Factor	Distance Index	Additive Priority Score	Weighted Priority Score
Brassica tournefortii	Sahara Mustard		3		3		2.00		2.17		3		2.00	15.17	18.17
Tamarix sp.	Tamarisk		3		2		2.46		2.56		3		2.05	15.07	18.07
Hypericum canariense	Canary Island Saint John's Wort		3		3		3.00		3.00		2		2.00	16.00	18.00
Lepidium latifolium	Perennial Pepperweed		3		3		1.00		2.91		3		1.67	14.58	17.58
Hedera sp.	Unknown Ivy		3		3		2.82		3.00		2		1.50	15.32	17.32
Carpobrotus edulis	Iceplant		2		2		2.66		2.60		3		1.65	13.92	16.92
Cirsium vulgare	Bull Thistle		3		3		2.25		2.98		2		1.60	14.83	16.83
Phalaris sp.	Hardinggrass		2		3		2.81		2.90		2		1.67	14.38	16.38
Olea europaea	Olive		3		3		2.71		2.95		1		2.71	15.37	16.37
Arundo donax	Giant Reed		1		2		2.75		2.93		3		1.46	13.15	16.15
Asphodelus fistulosus	Onionweed		3		3		1.00		3.00		2		2.00	14.00	16.00
Lactuca serriola	Wild Lettuce		3		3		2.13		2.02		2		1.83	13.98	15.98
Myoporum laetum	Lollypop Tree		3		2		2.72		2.25		2		1.93	13.90	15.90
Cyperus papyrus	Papyrus		3		3		2.80		3.00		1		2.00	14.80	15.80
Foeniculum vulgare	Fennel		2		1		2.54		2.40		3		1.72	12.66	15.66
Cortaderia selloana	Pampas Grass		1		1		2.88		2.51		3		2.21	12.61	15.61
Washingtonia robusta	Mexican Fan Palm		3		1		2.85		2.92		2		1.71	13.48	15.48
Tree sp.	Unknown Tree		3		3		2.83		2.68		1		1.83	14.34	15.34
Cactoideae sp.	Unknown Cactus		3		3		3.00		2.26		1		2.00	14.26	15.26
Opuntia ficus-indica	Mission Cactus		3		3		2.57		2.69		1		2.00	14.26	15.26
Callistemon sp.	Bottlebrush		3		3		2.73		2.97		1		1.50	14.20	15.20
Paraserianthes lophantha	Plume Acacia		3		3		2.85		2.60		1		1.67	14.11	15.11
Schinus terebinthifolius	Brazilian Pepper Tree		3		3		2.73		2.76		1		1.54	14.02	15.02
Buddleja davidii	Butterflybush		3		3		2.00		3.00		1		2.00	14.00	15.00
Yucca sp.	Unknown Yucca		3		3		3.00		3.00		1		1.00	14.00	15.00
Silybum marianum	Milk Thistle		3		3		2.47		2.21		1		2.17	13.85	14.85
Agave americana	Century Plant	x1	3	x1	3	x1	2.64	x1	1.96	x2	1	x1	2.11	13.71	14.71
Tropaeolum majus	Garden Nasturtium		3		3		2.51		2.98		1		1.20	13.70	14.70
Stipa trichotoma	Mexican Feather Grass		3		3		2.11		1.35		2		1.17	12.63	14.63
Encelia farinosa	Brittlebush		3		3		2.00		2.00		1		2.50	13.50	14.50
Glebionis coronaria	Garland Chrysanthemum		3		3		1.13		2.20		2		1.00	12.33	14.33
Atriplex semibaccata	Australian Saltbush		2		2		2.12		2.14		2		1.80	12.06	14.06
Pennisetum setaceum	Fountain Grass		2		2		2.64		1.82		2		1.56	12.03	14.03
Ulmus parvifolia	Chinese Elm		3		3		2.67		2.33		1		1.00	13.00	14.00
Carduus pycnocephalus	Italian Thistle		1		2		2.75		2.51		2		1.66	11.92	13.92
Pinus sp.	Unknown Pine Tree		2		3		2.84		2.07		1		1.94	12.85	13.85
Piptatherum miliaceum	Smilo Grass		3		2		2.75		2.86		1		1.20	12.81	13.81
Robinia pseudoacacia	Black Locust		3		3		2.49		2.31		1		1.00	12.80	13.80
Nerium oleander	Oleander		3		3		2.00		2.00		1		1.67	12.67	13.67
Eucalyptus sp.	Eucalyptus		1		2		2.63		2.39		2		1.50	11.52	13.52
Echium candicans	Pride of Madeira		2		2		2.91		2.40		1		1.96	12.27	13.27
Acacia cyclops	Cyclops Acacia		1		1		2.64		2.47		2		2.03	11.15	13.15
Nicotiana glauca	Tree Tobacco		1		1		2.72		2.33		2		2.09	11.14	13.14
Phoenix canariensis	Canary Island Date Palm		2		2		2.76		2.47		1		1.82	12.05	13.05
Brassica sp.	Unknown Mustard		3		3		1.00		3.00		1		1.00	12.00	13.00
Conium maculatum	Poison Hemlock		1		1		2.69		2.55		2		1.72	10.96	12.96
Gazania sp.	Gazania		3		3		2.85		1.09		1		1.00	11.93	12.93
Marrubium vulgare	Horehound		3		1		2.49		2.22		1		2.04	11.76	12.76
Cynara cardunculus	Artichoke Thistle		1		1		2.55		2.27		2		1.93	10.75	12.75
Grass sp.	Unknown Grass		2		3		2.19		1.52		1		1.67	11.37	12.37
Ricinus communis	Castor Bean		3		2		2.36		1.22		1		1.73	11.31	12.31
Schinus molle	Peruvian Pepper Tree		2		2		2.56		2.10		1		1.59	11.25	12.25
Limonium ramosissimum	Algerian Sea Lavender		2		3		1.53		2.04		1		1.50	11.07	12.07
Picris echioides	Prickly Sowthistle		1		3		2.14		1.89		1		1.67	10.70	11.70

CAL-IPC Rank Index values displayed in **RED** are species that have yet to be assessed by CAL-IPC. Instead, the ranking value was inferred based on WCS observations on NROC properties and the Southern California region as a whole.

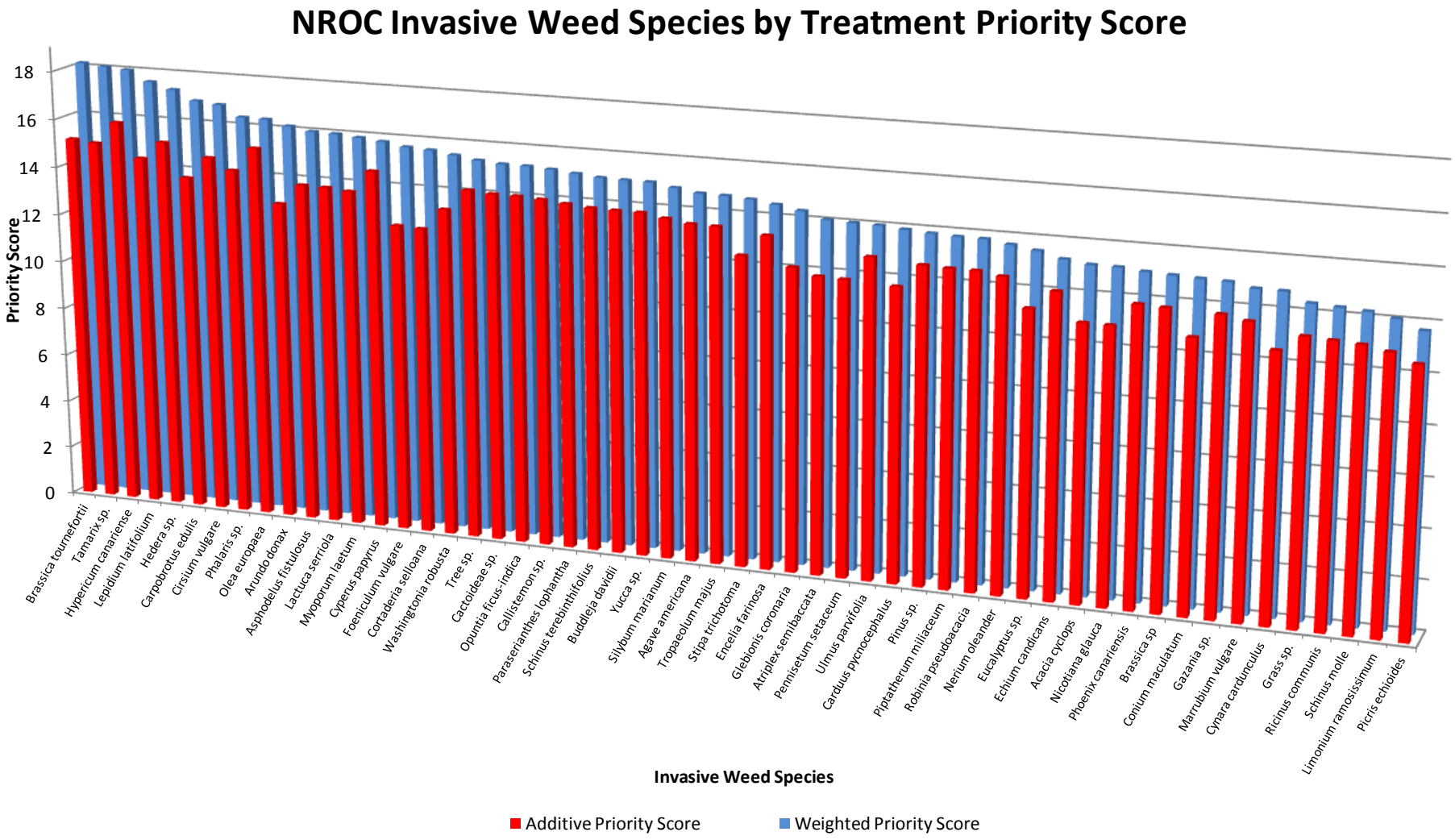

Figure 13. Bar chart summarizing the *Additive* and *Weighed Priority Scores* sorted from high to low ranking by the *Weighed Priority Score Index.*

As more data become available, this prioritization can be modified to include more factors that may influence relative species priority rankings. Information regarding future treatment success, species treatment cost, habitat recovery following treatment, wildlife habitat use, and treatment efficiency considerations (i.e. treatment of multiple species clusters to save time) could prove helpful in further refining the prioritization over time. Based on observations made on Irvine Ranch and Santa Cruz Island, five year cycles appears to be the optimal amount of time before repeating a property-wide invasive plant survey. This time period allows for treatment efforts to take effect while indentifying new pioneer weed populations before they become completely entrenched.

When reviewing the results of either prioritization method, *Cynara cardunculus* stands out as one of the lowest ranked species despite historically being the primary invasive species targeted for treatment within the NROC Coastal Subregion (Dickens 2014). In consideration of this outcome, it is important to remember that this document is an invasive plant species ***eradication*** prioritization, not an integrated weed management plan. An eradication prioritization attempts to recognize and rank those species occurring on the left side of the invasion curve before the plants have become well-established in the natural system (Figure 8). Once a species becomes entrenched and widespread, treatment efforts shift from an expectation of eradication to one of containment, asset-based protection and long-term management (Figure 8). As a result, those species that have received a high eradication prioritization ranking are likely eradicable relative to those of the lower ranked species. The low prioritization ranking of *C. cardunculus* indicates that the species is likely not eradicable due to its large population size and infestation area. The species' prioritization rank is further reduced because *C. cardunculus* is listed as only moderately ecologically "impactful" (rank of 2 on the Cal-IPC Rank Index) and tends to infest habitat of low to moderate habitat management priority (rank of 2.2 on the Habitat Priority Index). The cumulative outcome of these various index ranking factors results in a low eradication prioritization ranking for *C. cardunculus* (Table 12).

However, more than eradication prioritization alone should be taken into consideration when developing an integrated weed management plan. When developing such a plan, all areas of the invasion curve should be addressed (Figure 8). Grounds maintenance protocols and early detection programs should be developed to prevent and identify pioneer invasive plants. An eradication program that works to remove high priority ranking species for the system should be developed. Lastly, a detailed assessment of the low ranking species should be performed to determine if conflicts occur in areas that support endangered species, habitat restoration sites, recently burned habitats or other areas of particularly high natural resource value. This management plan should determine what proportion of available resources should be allocated to perform management activities along all regions of the invasion curve. Resource distribution should be based on a balanced evaluation of funding availability and the management objectives of both the NROC and member stakeholders.

There is evidence that years of targeted *C. cardunculus* treatment have resulted in positive habitat quality trends in some areas of the NROC Coastal Subregion (Dickens 2014). However, the gains obtained through past management activities were performed at the expense of alternative management activities that could have benefited the NROC in other ways. For this

reason, a comprehensive review of past management actions should be taken into account when developing the integrated weed management plan.

It is the hope of WCS that this invasive plant survey and resulting prioritization ranking system will provide land stewards with a useful first step towards developing an integrated weed management plan. We also hope that the results of this survey prove valuable beyond the expectations envisioned for the project. For example, when producing a map summarizing these survey results, the relationship between open space parcel size and the degree of weed infestation was visually striking (Figure 14). The center most portions of the largest parcels of coastal open space are virtually free of invasive plants relative to those smaller parcels occurring along the human interface. We feel that this map and Figure 14 tells the story of human encroachment and can be helpful in both communicating with future funding providers and the public.

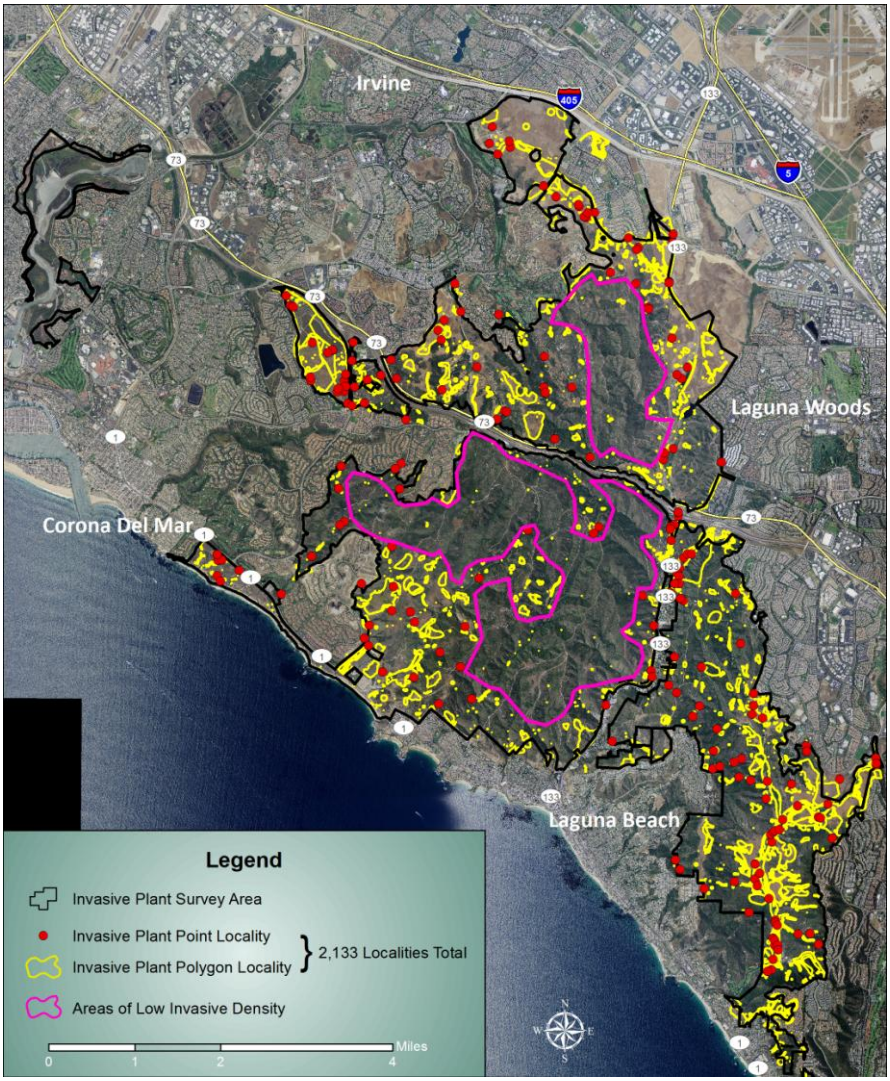

Figure 14. Map that illustrates the substantial reduction in invasive plant infestation towards the center of the larger unfragmented sections of open space where the disturbance rate is presumably lower.

5.0 Acknowledgements

WCS would like to thank the California Department of Fish and Wildlife, County of Orange (OC Parks), Laguna Canyon Foundation, Irvine Ranch Conservancy and the NROC for providing financial support for this weed survey and prioritization. We are grateful for the opportunity to work with Nature Reserve of Orange County helping to protect one of the last remaining wildlands of Southern California. A very special thank you Dr. Milan Mitrovich and Dr. Jutta Burger for their tireless support of the project and excellent coordination and oversight.

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