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Continuing Assessments of Recovery Requirements for *Astragalus lentiginosus* var. *coachellae*: Evaluating the Potential Effects of Disturbance, Habitat Fragmentation, and Exotic Species

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Preface and Acknowledgements

This report represents the second phase of our on-going *Astragalus lentiginosus* var. *coachellae* studies, initially funded under Agreement No. P0485100 with the California Dept. of Fish and Game (CDFG). Our first report, entitled "Evaluating the Biological Conservation Status of the Coachella Valley Milkvetch (*Astragalus lentiginosus* var. *coachellae*)," was completed in October, 2007.

The current work and this resulting follow-up report (covered by CDFG Agreement No. P0685100) should be considered a supplement to the more comprehensive 2007 report, which is referenced here throughout. Some of the general or background statements in this report concerning the biology and ecology of ASLECO or its habitat, etc., are based on data or observations from the 2007 report (covering the 2005-2007 field seasons).

This phase of the project was once again greatly facilitated by CDFG staff, especially Mary Ann Showers, as well as Department of Botany and Plant Pathology staff and students at Oregon State University. Photos represent the collective effort of the authors unless otherwise noted.

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Introduction

Management and recovery assessments for the federally endangered Coachella Valley milkvetch (*Astragalus lentiginosus* var. *coachellae*—ALESCO) were initiated in 2005 in cooperation with the California Department of Fish and Game. Tasks that were performed during this initial phase of the project included sampling accessible populations in order to gather a demographic snapshot of the species; implementing a sampling scheme to assess plant longevity, survival, and reproduction (i.e., flower, fruit, and seed production); evaluating seed production, including an estimate of pre-dispersal seed predation and the types and frequency of predators; estimating the breeding system, and assessing the role and diversity of insect pollinators; identifying the potential for *ex situ* seed banking, based on population sizes and annual seed crop levels; considering the potential for reintroduction (from greenhouses starts or seeds) as a potential recovery tool; and developing baseline conservation protocols, focusing on habitat fragmentation, reproductive ecology, population dynamics, and life history.

Although ALESCO remains locally common in a very few areas, and has dozens of smaller extant populations persisting in scattered localities around the Coachella Valley, our observations suggest it is nonetheless highly endangered. Remaining sites are lost each year to large-scale, permanent development (Fig. 1), such as housing tracts, golf courses, shopping centers, and resorts,

Figure 1. Contemporary use for ASLECO habitat in the Coachella Valley.

particularly west of Interstate 10. Under the current development scenario, the Coachella Valley milkvetch is under serious threat of extinction in this significant portion of its range. Refuges from immediate development still exist for ALESCO just north of Palm Springs (mostly on BLM public lands) in the Snow Creek-Whitewater-Windy Point area, and along the east side of the valley in the Coachella Valley National Wildlife Refuge (and adjacent private conservation preserves). Although these areas are ostensibly protected from major development, they are all subject to localized disturbance (ATVs, etc.), heavy infestations of exotic weeds, or usually both.

Figure 2. ASLECO plant occurring on dune crest in the Coachella Valley National Wildlife Refuge, with Saharan mustard in the background.

Prior observations have showed that ASLECO can be a taprooted annual—but more often a short-lived, facultative perennial—which requires non-stabilized, drifting substrates to develop and sustain populations (Fig. 2). Appropriate habitats are typically on or near dunes and in loose, sandy washes. ASLECO is a narrow endemic found only in the upper Coachella Valley (past reports of populations occurring well to the east, near Desert Center, are now known to be misidentifications of the var. *variabilis*). Plants are typically very fecund, and produce most seeds from outcrossing (although at least partially self-compatible, the flowers are rarely autogamous in nature). Less than one percent of pollinator visits were from native bees in the two years of observation—however, honeybees (potentially from "Africanized" hives) aggressively visit ASLECO flowers, especially in dense populations, resulting in high levels of seed set. And although a modest percentage of seeds are lost to pre-dispersal predation, the overall impact to the seed bank from predators appears negligible.

Without human-related disturbances, populations of ASLECO would have undoubtedly continued to reproduce and thrive among the shifting dunes of the Coachella Valley. However, our range-wide observations indicate that few, if any, of the populations persisting today exist in pristine areas. In fact, virtually no intact and unaltered habitat suitable for ASLECO appears to remain anywhere in the valley. Much of this conversion has resulted from the direct impact of urban growth (see Fig. 1), with substantial areas of habitat completely destroyed over the last several decades. ASLECO sites that still remain are in the process of being stabilized, due to the indirect effects of urbanization (from habitat fragmentation and soil compaction resulting from development, ATV traffic, dumping, etc.), or from infestations of exotic weeds that both reduce substrate movement and create a highly competitive environment for ASLECO seedlings. Significant weeds include Saharan mustard (*Brassica tournefortii* - BRTO) and, to a lesser extent Russian thistle (*Salsola kali*), although others, such as salt cedar (*Tamarix* spp.), may be locally important. Over the several years of this study alone, the explosion of Saharan mustard, in particular, has further devastated the dune environments that support ASLECO and other herbaceous natives. The unprecedented exotic seed bank that is forming (an estimated average of 130,000 seeds per large *Brassica* plant were dispersed in 2005, when millions of mustard plants were present in ALESCO habitat) ensure that similar outbreaks will be a regular future occurrence (Fig. 3).

Figure 3. Saharan mustard dominated thousands of acres at the Coachella Valley Wildlife Refuge in April, 2008, in habitat formerly available to ASLECO and other endemics. Comparable (or worse) weed outbreaks were observed in 2005, 2006, 2007, and 2009.

Project Goals

Human-caused disturbances and the presence of exotic weeds are plainly the most critical factors affecting ASLECO habitat and potential recovery. Areas with static substrates that lack the necessary shifting sand environment, or those subject to extreme and destructive habitat modifications, have been negatively correlated with milkvetch recruitment and reproduction. However, observations during the 2005-2007 phase of this project suggested that *light to moderate* disturbance (in what had otherwise become decadent, stabilized habitats) may benefit population dynamics. The presence of ASLECO in such settings is believed to mimic the normal reaction of plants to the natural sand movements found on unfettered dunes and washes. Considering the number of milkvetch sites that appear to have been lost to development, and the potential for future impacts to the species from urbanization, dune stabilization, and increasing competition with exotics, species recovery efforts incorporating re-introduction work or habitat manipulations may need to be considered. To help determine the feasibility of such an approach, we reviewed the current field status of ASLECO, focusing on urbanization effects and the threat from exotic species (particularly Saharan mustard). To accomplish this, we:

- Developed a disturbance (or vulnerability) index for ASLECO, based on an evaluation of a large subset of extant populations—the goal was to rank populations according to their (1) level of disturbance and (2) prospect for long-term survival, focusing on the degree of infestation by exotics, exposure to urbanization, etc., and how this might influence the potential for habitat fragmentation, population isolation, interrupted gene flow, and extirpation due to competitive exclusion;
- Evaluated the potential role of disturbance in facilitating ASLECO population maintenance;
- Assessed whether directed (or planned) disturbance could be used as a recovery tool to stimulate ASLECO populations in areas stabilized by the effects of exotics or the urban landscape (where might this be possible, and would negative interactions with exotics make this problematic?);
- Evaluated the possible effects of Saharan mustard (BRTO) within ASLECO populations by considering the relative germination timing and ecology of SM vs. ASLECO; growth rates; the response of SM to disturbance in ASLECO sites; the potential for allelopathic interference by SM; and the likelihood of pollination-related competition;
- Continued with cultivation work in the greenhouse, to assess whether it is possible to cultivate ASLECO plants for reintroduction efforts. (Our 2005-06 work shows that ASLECO seeds readily germinate and grow – we need information on how quickly plants can reach a size suitable for outplanting, and if any special requirements, such as mycorrhizae, *Rhizobium*, etc. are required for successful cultivation); and
- Developed a report focusing on the potential impacts of Saharan mustard and other exotics, the role of disturbance at maintaining or curtailing ASLECO metapopulations, and the current status of the species in relation to Coachella Valley development.

Methods and Results

ASSESSING THE LEVEL OF DISTURBANCE AMONG ALECSO POPULATIONS

Using site directions and GPS coordinates provide by the CDFG-Natural Diversity Database in 2007, we visited and sampled 51 ASLECO populations with previously assigned Occurrence Numbers from across the Coachella Valley. Site visits were completed during December, February, March, and April (in 2008 and 2009). For each population, we:

- Recorded the date visited
- Walked the site to establish the population perimeter and population center [if plants were not seen but habitat appeared suitable (i.e., the site was not wiped out by development, so ASLECO could conceivably have been there somewhere, or could re-appear in the future), cover measurements (described below) were still recorded].
- Recorded dominant native associate taxa
- Evaluated (at least to the nearest 10%, or more accurate if feasible) (1) the overall collective cover of all plants on site; (2) the total cover of all herbaceous species; (3) the total cover of all woody vegetation; and (4) the total cover of all exotic weeds deemed significant at the site (e.g., *Brassica*, *Salsola*, *Schismus*, *Erodium*, etc.). Cover percentages were typically attained by averaging the estimates of 3 observers, who initially walked over each site, and then stood at the estimated center of the ASLECO population to approximate cover. Meter square plot frames were selectively used to calibrate the cover of species or patches, to increase the accuracy of estimations.

To rank ASLECO populations according to *potential vulnerability*, we established an *index* as a means of comparing each of the 50 sites we sampled (described below, and in the caption for Table 1). To accomplish this we:

- Assigned a *level of urbanization* to the population: **5** = population not present, and may be extirpated due to development; **4** = is present, and is significantly isolated from other populations due to fragmentation with limited opportunity for gene exchange, and appears to be in imminent danger of extirpation due to development, OHV activity, or other actions; **3** = is locally isolated, with no meaningful chance for gene exchange with other populations, but is not immediately threatened by development or other activities; **2** = is known to be part of a metapopulation complex (i.e., is less fragmented or isolated by urbanization), but individually is in danger of extirpation due to development, OHV activity, or other actions; and **1** = appears to be part of a functioning metapopulation and is not in immediate danger of extirpation due to development, etc.
- Determined a *cover class for Saharan mustard* (BRTO), by far the most prolific exotic, within the ASLECO population perimeter at each site—BRTO cover percentages were typically attained by averaging the observations of 3 observers standing at the estimated center of the population after having walked the entire site, as described above (**5** = 50-100% BRTO overall site cover; **4** = 25-50% overall cover; **3** = 5-25% overall cover; **2** = 1-5% overall cover; and **1** = trace to 0% overall cover).
- Estimated (in addition to the overall weed cover for a site) the "*potential for long-term weediness*" from heavy seed bank input, promoted by the presence within ASLECO populations of microsites that support super high biomass BRTO patches (= >100% total cover within patches) (Figs. 4

and 5) (**5** = 50% or more of the total BRTO cover within an ASLECO population consisted of super high biomass patches; **4** = 25-50% super high biomass cover; **3** = 5-25% super high biomass cover**; 2** = 1-5% super high biomass cover **;** and **1** = trace to 0% high density biomass cover).

- Created a *site vulnerability index*, which =

$$\frac{\textit{urbanization level*BRTO cover class*weediness potential}}{100}$$

The lower the index score, the less the population is ostensibly threatened (with 0.01 the least vulnerable rating possible, and 1.25 the most vulnerable).

Although by no means perfect, the index provides an objective ranking system for sampled populations, in terms of their current susceptibility to what are considered the greatest threats to ASLECO, i.e., (1) *urban development* (and the potential this has for habitat destruction, fragmentation, and reductions in reproductive potential), (2) the immediate presence of *Saharan mustard* (and the accompanying stabilization of sandy habitats this is causing, along with interspecific competition), and (3) the potential for *long-term biodegradation* of sites (via the permanent establishment of Saharan mustard and other exotics, supported by the creation of massive seed banks).

Disturbance and demographic field data for the 51 ASLECO sample populations were collected during the 2008 and 2009 growing seasons, and are presented in **Table 1**.

Of the 51 populations in the Natural Diversity Database whose locations were made available by CDFG, 35 (or 69%) were relocated with at least one ASLECO plant in either 2008 or 2009. Of the others, 6 populations (12%) were positively confirmed as extirpated (being literally overtopped by development), 2 (4%) retained no plants or habitat that would have supported ASLECO (so these are assumed to be erroneous reports), 2 (4%) had no ASLECO plants but did have habitat present (we went ahead and took cover and vulnerability measures on these), 2 represented the wrong taxon (these were var. *variabilis*, from sites situated near Desert Center), and 4 (8%) could not be re-located (we felt these sites might have had populations, if they still existed, but the site location data were inadequate).

Figure 4. Heavy mustard cover was common in areas near Snow Creek Rd.

So of the 37 ASLECO sites that we measured, total plant cover within the population perimeters averaged close to 63%. Of this total, about 12% was comprised of woody species, and the rest a mix of native and exotic herbaceous

Table 1. Disturbance rankings for 51 sampled ASLECO populations in the Coachella Valley. In the table, ***Site occurrence no.*** refers to the population number assigned by the CDFG-Natural Diversity Database.

Population size (often given as a range) is an approximation of the number of adult and juvenile ASLECO plants present on the sampling date, arrived at after a reasonably thorough investigation of the site. It should be noted that the intent of the site surveys were not to provide a complete census, per se, but to gather information on general status and relative population sizes (for comparison with past site records, as well as to highlight the potential relative demographic importance of sites).

As described in the text, ***cover data*** were estimated from the averaged observations of multiple observers, who walked through the sites at length prior to attempting estimations. While traversing the sites, the observers (1) established a population perimeter for ASLECO, (2) used plot frames to assist in calibrating cover estimates for dominant species (as needed), and (3) determined a center point for the population (which may or may not have corresponded to the population GIS data provided by CDFG). The area of populations varied considerably by site, although the vast majority covered less than 0.5 hectare (or often much smaller). Observers then gathered at the ASLECO population center point to discuss site characteristics, and to reach a consensus on within-population cover estimates for woody, herbaceous, and exotic vegetation. Although considerable time was spent at each site, the goal was not to gather painstakingly accurate cover data, and the level of accuracy is not equivalent to what might be achieved using a more rigorous sampling scheme (with numerous plots or transects). However, the data do provide a reasonable and comparative snapshot of the threat level faced by the various sample populations.

Urbanization level is a more or less subjective evaluation of the threats posed by development to a given site (through observations of direct habitat impacts and range fragmentation). Complete extirpation is obviously not a subjective measure (the populations listed below as "extirpated" are those that are clearly gone—e.g., the site is now under a housing tract, golf course, or other landscaping). Sites that are still physically intact, however, exhibit a range of impacts from urban sprawl and are not easily pigeon-holed. So as is also described in the text, the aim here was to categorize this continuum into groupings, by ranking site vulnerability according to our view of the immediacy of threat from development, in combination with the potential impacts to dispersal and gene flow due to population isolation and fragmentation.

Data in the ***BRTO cover class*** column simply represent the cover estimates made by observers, organized into classes (with 5 representing the heaviest cover, and 1 the least—see text for details).

The ***BRTO density class*** column includes a rough estimate of relative patch density for Saharan mustard at the various sample sites. The way cover data are typically estimated, open-canopied species such as the mustard can have high overall site coverage, and

Figure 5. Extremely dense mustard patches (often in excess of 100% total cover) characterized many parts of the Snow Creek/Windy Point Conservation Area.

yet not be particularly dense. In such cases, simple cover data may not be the best indicator of the long-term potential for persistence of the species at a given site (as expressed by seed bank contributions). Fig. 5 shows how Saharan mustard can occur locally in extremely dense patches that greatly exceed 100% cover, a result of overlapping and intertwined plants. Such high-biomass patches contribute disproportionately to the seed pool on a per-area basis, and represent greater threats to ASLECO habitat than less dense populations. To try and quantify this, we estimated how much of the overall mustard cover at a site could be classified as "super dense" (i.e., having >100% cover)—see additional details in the text for the definition of the 5 cover classes.

Finally, the ***Vulnerability index*** is simply the product of the Urbanization, BRTO cover class, and BRTO density class columns expressed as a percentage.

Site occurrence no.	Date	Est. ASLECO population size	Dominant native taxa	Total plant cover (%)	Total woody cover (%)	Total herb. cover (%)	Total exotic cover (%)	Urban. level	BRTO cover class	BRTO density class	***Vuln. index***
1*	Apr-08	60-70	*Larrea, Encelia, Psorothamnus*	65	30	35	20	2	3	1	**0.06**
2	Apr-08	Extirpated by development									
3a	Apr-08	150-200	*Dicoria, Larrea, Ambrosia*	90	15	80	75	2	5	5	**0.5**
3b	Apr-08	150-200	*Dicoria, Larrea, Ambrosia*	85	10	80	75	2	5	5	**0.5**
4	Apr-08	80-100	*Larrea, Psorothamnus, Encelia*	95	5	90	85	3	5	5	**0.75**
5	Apr-08	25	*Larrea, Dicoria, Ambrosia*	75	15	65	60	2	5	4	**0.4**
6a	Mar-08	15-20	*Ambrosia, Larrea*	60	15	50	50	3	5	5	**0.75**
6b	Mar-08	250-300	*Isomeris, Larrea, Ambrosia*	60	10	60	5	2	3	1	**0.06**
6c	Mar-08	100-150	*Prosopis, Larrea, Ambrosia*	45	20	40	40	2	4	5	**0.4**
8	Mar-08	Extirpated by development									

9	Mar-08	15-20	*Larrea, Ephedra, Lepidospartum*	25	15	15	15	2	3	5	**0.3**
10	Apr-08	50-100	*Larrea, Ephedra, Lepidospartum*	40	20	20	40	2	4	5	**0.4**
12	Apr-08	Not locatable									
13	Apr-08	50-100	*Larrea, Ephedra, Lepidospartum, Ambrosia*	60	10	50	40	2	4	5	**0.4**
14	Mar-08	15-20	*Ambrosia, Larrea*	70	10	70	70	2	4	4	**0.32**
15	Apr-08	9	*Larrea, Ephedra, Lepidospartum, Ambrosia*	80	15	70	60	2	5	5	**0.5**
16	Apr-08	80-100	*Larrea, Ambrosia, Psorothamnus*	50	5	40	35	4	4	1	**0.16**
17	Mar-08	1	*Prosopis, Larrea, Ambrosia*	65	5	60	60	2	5	5	**0.5**
18	Mar-08	Extirpated by development									
19	2006	This site is not ASLECO									
20	2006	This site is not ASLECO									
21	Mar-08	Extirpated by development									
22	Apr-08	Not locatable									
23	Apr-08	0	*Ambrosia, Larrea, Palafoxia, Dicoria*	40	5	35	30	5	4	2	**0.4**
24	Mar-08	50-60	*Ambrosia, Larrea*	50	20	30	35	4	4	2	**0.32**
25	Mar-08	0	*Ambrosia, Larrea*	55	15	40	40	5	4	4	**0.8**
26	Apr-08	100-150	*Ambrosia, Larrea, Dicoria*	50	10	40	20	2	3	1	**0.06**

27	Apr-08	75-100	*Ambrosia, Larrea, Atriplex, Dicoria*	60	15	45	20	2	3	2	**0.12**
28	Mar-08	None seen; not correct habitat	Desert riparian								
29	Apr-08	Extirpated by development									
30	Apr-08	100-150	*Larrea, Ambrosia, Psorothamnus*	80	5	75	70	4	5	5	**1.0**
31	Mar-08	Extirpated by development									
32	Apr-08	40-50	*Larrea, Ambrosia, Psorothamnus*	55	20	35	25	2	3	3	**0.18**
33	Apr-08	None seen; not correct habitat	Bouldery slopes								**0**
34	Apr-08	50-100	*Ambrosia, Larrea*	85	5	80	70	5	5	5	**1.25**
35	Apr-08	150-175	*Larrea, Ambrosia, Psorothamnus, Croton, Dicoria*	50	15	35	20	1	3	2	**0.06**
36	Mar-08	Not locatable									
37	Mar-08	Not locatable									
38	Apr-08	6	*Larrea, Ambrosia*	85	5	85	80	2	5	5	**0.5**
39	Apr-08	200-225	*Ambrosia, Larrea, Dicoria*	75	5	75	70	4	5	5	**1.0**
40	Mar-08	100-150	*Ambrosia, Larrea, Dicoria*	30	1	30	10	1	3	1	**0.03**
41	Apr-08	500-600	*Ambrosia, Larrea, Palafoxia, Dicoria*	45	5	40	30	2	4	2	**0.16**
42	Apr-08	40-50	*Larrea, Ambrosia*	65	20	50	45	3	4	3	**0.36**

43	Mar-09	100-150	*Larrea, Ambrosia, Psorothamnus, Prosopis, Dicoria*	80	30	55	50	3	5	4	**0.6**
44	Mar-09	250-300	*Larrea, Ambrosia, Croton, Hymenoclea*	70	5	70	65	4	5	5	**1.0**
45	Mar-09	15-20	*Larrea, Ambrosia, Psorothamnus*	70	5	65	65	4	5	5	**1.0**
47	Apr-08	60-70	*Larrea, Ambrosia, Psorothamnus, Dicoria*	40	15	25	15	2	3	1	**0.06**
48	Mar-09	25-30	*Larrea, Ambrosia, Croton, Atriplex*	80	15	70	65	2	5	5	**0.5**
49	Apr-08	30-35	*Larrea, Ambrosia*	55	15	45	40	3	4	2	**0.24**
50	Apr-08	25-30	*Larrea, Croton, Psorothamnus*	45	15	30	30	3	4	3	**0.36**
51	Apr-08	8	*Larrea, Croton, Psorothamnus, Tequilia*	75	10	70	65	4	5	5	**1.0**
Mean				60.27	12.05**	50.81**	43.92***	2.68	4.05	3.46	**0.43**

* Site occurrence numbers in **bold** represent populations with plants occurring at least partially in human-disturbed areas.

** The combined cover for woody and herbaceous vegetation (62.86%) is slightly higher than total site cover, due to the overtopping of some herbaceous species growing under woody plant canopies.

*** Estimated to be >99% *Brassica tournefortii*.

taxa. Roughly 44% of the total veg cover consisted of one species: *Brassica tournefortii*. In other words, of the nearly 50% of the ground that was covered by herbaceous plants at the 37 measured sample sites, we estimated that 88% of this was covered by Saharan mustard alone (Fig. 4). Although other factors clearly have an impact on ASLECO populations, most notably the spatial effects of urbanization (that result in habitat fragmentation and population isolation), these impacts, while serious, pale in comparison with the threat posed by the mustard invasion.

We concede that mustard cover was only estimated for a single season at each site, and that it can be difficult to draw conclusions about a threat with a single year's data. However, during this overall project, our observations in the Coachella Valley (including every field season since 2005) suggest that neither 2008 or 2009 were unusually low in terms of mustard production, and that cover values comparable to those reported in Table 1 occurred throughout much of the remaining ASLECO habitat every year (except 2005, which was especially high). And similar to the threat posed by urbanization, we feel that the mustard incursion into ASLECO habitat is a largely *irreversible impact* at the landscape level. Considering that individual large mustard plants are each capable of dispersing tens of thousands of seeds (as noted in our previous work), and multiple millions of mustard plants have been annually dumping seed into the Coachella Valley seed pool over recent decades, it is a virtual certainty that Saharan mustard will remain a continuous and pervasive presence in ASLECO habitat. If ASLECO goes extinct in the foreseeable future, it will most likely be due to the competitive effects of Saharan mustard.

A potential conservation tool that can mitigate for population loss is the recreation of extinct populations or the augmentation of existing ones. Assuming it would be possible to germinate, grow, and outplant ASLECO plants back into the wild, sites that are administratively protected as well as ecologically suitable would be required. The information presented in Table 1 suggests that locating such sites will be a challenge, at least from an ecological perspective. As discussed above, we used basic measures of urbanization and exotic species cover to create a vulnerability index for the sampled sites, which can be used to subjectively rank the conservation status of ASLECO populations. Although each site has other intrinsic characters that would need to be considered individually, the index provides a relative, if somewhat subjective, measure that can be used to estimate a population's potential contribution to ASLECO recovery.

Using an index cutoff of 0.40 (for populations close to or above the index mean), we can attempt to identify sites that would likely represent poorer options for population re-introduction or augmentation. These sites (typified by Site 25—see Fig. 6) have the highest covers of exotic species, and also usually occur in habitat that has been the most fragmented by development (cityscapes, roadways, etc.), although not always. A good example in this case is Site 38 (Fig. 7), which although part of the ASLECO metapopulation that is scattered over the multi-agency administered Coachella Valley Preserve and nearby areas, is nonetheless severely threatened by high densities of Saharan mustard. Even if adult plants could be successfully transplanted in such areas, seedlings would likely face significant competition for water, space, and other resources.

Figure 6. Site No. 25, near Desert Hot Springs, which has been impacted by local development and high levels of Saharan mustard. This would be a poor candidate for ASLECO re-introduction work.

Figure 7. Site No. 38, adjoining the Coachella Valley National Wildlife Refuge. Although not immediately threatened by development, this site is seriously compromised by Saharan mustard.

So sites with lower index values (i.e., at or below 0.40) should be focused on initially if programs are ever implemented to re-introduce or augment populations, or to secure additional higher quality populations or habitat via land acquisition (through purchase or easement). The obvious spotlight here should be on low index value sites that support larger populations, especially any that might occur on public property where plants (theoretically) would benefit from management resulting in longer-term survival. However, even the best of such sites are now significantly impacted, and there are few remaining locations that are particularly promising.

One general area we visited that still contains reasonable habitat is the so-called “Big Dune” in the central Coachella Valley, just west of Interstate 10, much of which is under the control of the Agua Caliente tribe. Although we were unable to secure permission to comprehensively walk on or sample the area, it was easy enough to make observations from adjacent public roadways (we walked the perimeter of the several thousand acre polygon bounded by E. Ramon Rd., Interstate 10, Dinah Shore Dr., and Los Alamos Rd. on the north, east, south, and

Figure 8. Looking west from Bob Hope Dr. towards ASLECO habitat on presumed Agua Caliente tribal lands. Potentially subject to development, this areas represents some of the best remaining acreage within the urbanized valley that still retains a relatively intact aeolian ecosystem.

west, respectively). The open, as yet (more or less) still undeveloped nature of the dune system here permits aeolian sand movement (particularly in the areas most subject to winds—see the hillcrest in Fig. 8, showing Site 16 from Table 1), which is favored by ASLECO, and likewise appears to reduce establishment of Saharan mustard (we have also seen this on the higher dunes at the Coachella Valley Preserve, which are otherwise surrounded by heavy mustard infestations on the more stabilized flats—see Fig. 2). The mustard is definitely established on the Big Dune, but is often patchier and less extensive here. The area we walked around, although bounded by roads, is part of an extended corridor of adjoining dunes and sandy flats (to the north and east) that essentially parallel the interstate highway. This broad corridor forms an extensive network of ASLECO habitat that is only separated by a few roadways (and not major developments), so the impact of urbanization is as yet somewhat minimized. Extensive surveys were not part of this project and we didn't traverse much of this, but it is possible the entire area supports a more or less contiguous metapopulation of ASLECO. However, there is also strong potential that development of at least some of the area may occur down the road, since it is not owned by a public agency, and a single casino property is already on site along E. Ramon Rd. But even if unavailable for conservation, the area is worth noting in that it probably represents the most extensive remaining ASLECO habitat within the greater metro region.

Northwest of the metro area proper, extensive habitat for ASLECO appears again southeast of Gene Autry Drive and then extends west (south and west of the interstate) up through the Whitewater River floodplain to the wind energy parks west of Garnet (and the Amtrak Station). The wind farms (depicted in Fig. 9, which shows Site 26) cover some of the best remaining actual and

Figure 9. Wind energy parks along the Whitewater River floodplain, west of Garnet. Extant ASLECO populations, open wind-blown habitat for potential population establishment, and low densities of Saharan mustard make this one of the best remaining tracts of milkvetch habitat.

potential habitat for ASLECO. Despite the obvious disturbances caused by the installation and maintenance of the turbines, the winds here and otherwise low-impact human disturbances maintain excellent sand flow, and there is very little surface stabilization. Although Saharan mustard populations are established here in places, they are scattered and are probably kept at bay due to the substrate instability. This habitat is higher quality than the Big Dune area described above. As the Whitewater River wash continues to the northwest, good habitat persists to just beyond Windy Point, towards the base of the mountains. After that, as the wash becomes rockier near the Snow Creek area, habitat quality plummets and mustard populations dominate the landscape (Fig. 10).

Conclusions. The vulnerability index provided for the various sample populations in Table 1 can be used to rank their potential for "long-term survival," as well as their relative conservation value (in terms of usefulness for *in situ* conservation, and potentially as candidates for population re-introductions). Extant populations in most areas within the city limits of Coachella Valley area cities are poor candidates for recovery action. Their long-term prospects are limited, and their best uses (assuming they can be accessed) may be as seed donors for recovery work in other areas. That said, habitat on and near the Big Dune has greater potential (recognizing that this land is likely unavailable for recovery work), due to the large open areas that remain, and the somewhat reduced level of exotic infestation due to wind-aided sand movement.

The best habitat remaining occurs from Garnet west and north to Windy Point, where moderately deep sands, regular high winds, and occasional water flow in rainy winters help to maintain a highly dynamic surface environment. This area has a varied ownership, but incorporates public land managed by BLM, and probably includes the best remaining habitat for ASLECO.

Ironically, much of the region cited as important Core Habitat for ASLECO under the Coachella Valley Multiple Species Habitat Conservation Plan (CVMSHCP), as defined by specific Conservation Areas (CA)—such as the Whitewater Floodplain, Willow Hole, and 1000 Palms CAs—have some of the

Figure 10. Extensive mustard populations routinely infest formerly prime ASLECO habitat north of Snow Creek in the Whitewater River floodplain and wash, south of Interstate 10.

most impressive infestations of Saharan mustard in the valley. While at least some of the reasonably good ASLECO habitat near Windy Point is included in the Snow Creek/Windy Point CA, much of this CA (centered around Snow Creek Rd.) is heavily impacted by mustard (note Fig. 10). Some of the habitat among the wind energy farms may be covered by the Whitewater Floodplain CA, while all of the Big Dune area appears to be excluded from the HCP.

We debated whether to recommend specific sites for re-introduction or habitat remediation work, but felt such choices would best be made at the time any actual projects were approved and funded. Sites and habitats that appeared the most favorable during this study may potentially succumb later to increased weed cover or development, so up-to-date site assessments would be best.

Finally, it's worth reiterating that only a portion of the known sites for ASLECO were included in this evaluation. CVMSHCP staff indicated that they knew of additional populations not included in the CDFG Database information provided to us, and we made observations ourselves of what appeared to be several undocumented populations. However, to reduce the potential for bias, we elected to limit the sampling work to the 51 sites located by past observers that were identified by CDFG. They spanned the range of the species in the valley, and although apparently not a comprehensive offering of every known population, provided what we felt was a representative and unbiased appraisal.

THE EVALUATION OF DISTURBANCE IN SAMPLED POPULATIONS OF ASLECO, AND THE POTENTIAL ROLE OF DIRECTED DISTURBANCE IN FACILITATING POPULATION CREATION OR ENHANCEMENT

Every ASLECO population we sampled was impacted by some level of disturbance. This ranged from complete obliteration of sites by development, to indirect impacts caused by habitat fragmentation and exotic species. The CVMSHCP calls for minimizing human-caused disturbances to ASLECO, and indicates that impacts to the species from increased human activity, including OHV use and trampling, are important direct threats. Conversely, the CVMSHCP states that impacts to the species from wind energy parks have not been serious, and we came to this conclusion as well—ASLECO seems to thrive in some areas near the wind turbines, even though local population stability may be low due to the constantly shifting substrates. But this is the nature of a metapopulation.

So considering that wind-blown sand is favored by ASLECO, should management planning for the species aim to exclude all non-natural disturbances? In natural habitats where external threats are few, it makes sense to avoid human-caused impacts wherever possible. But most, if not all, ASLECO habitat is no longer natural, with much of it now severely altered due to the effects of urbanization and introduced species. Aeolian sand flow is still evident at sites near Garnet and Windy Point, for example, but most ASLECO sites within the urban boundaries of the Coachella Valley are segregated and isolated, and subject to on-going habitat stabilization. The latter is largely a result of surface consolidation, a manifestation of (1) development-related windbreaks (from buildings, roads, and landscaping) that eliminate the natural windblown sand transport system, and (2) an increase in substrate-anchoring biomass within Saharan mustard-dominated communities.

During our work in 2005 and 2006, we noted that ASLECO plants in city lots, as well as along railroad tracks, were positively correlated with proximity to disturbance (in these cases along the dirt tracks created by bicycles and railroad maintenance vehicles). The conclusion at the time was that the species ultimately did poorly in areas where the habitat had been stabilized, but that the low-impact disturbances effected by occasional pedestrian and vehicle traffic promoted germination and enhanced population dynamics. Rather than populations consisting primarily of large, older plants, as seen at many stabilized sites (Fig. 11), such microsites tended to support an array of mostly first and second year individuals (see Fig. 13), implying that reproduction and recruitment may be facilitated by disturbance.

Figure 11. A several year old ASLECO plant, observed in a Desert Hot Springs vacant lot.

In 2008 and 2009, we attempted to corroborate our earlier observations which suggested that ASLECO benefited from surface disturbance. At each of the study sites visited, we surveyed the site as well as the immediate vicinity (within ca. ¼ mile) for evidence that ASLECO was responding positively to disturbance. Positive responses would include significant numbers of plants growing along OHV tracks, in construction areas, along fencelines, in temporary parking areas, or other microsites that were created by low-impact substrate scarification.

Of the 35 sample sites with ASLECO plants present, 20 (or 57%) had at least some of these plants distributed in disturbed or semi-disturbed areas (see Table 1). Most had an estimated 25% or more of the plants occurring within such microsites, and several had higher percentages based on visual estimates. Moreover, populations with disturbed zones *averaged* larger estimated population sizes than those lacking obvious surface disturbances (114.55 plants per site in disturbed vs. 75.86 in undisturbed; means were used where ranges for population numbers are given in Table 1). The differences in plants per site in disturbed vs. undisturbed was largely the result of higher numbers of first (often non-reproductive) and second year plants present in disturbed populations.

Plants responding to disturbance were most often seen along trails (Figs. 12 and 13), but were also observed in lots around rural businesses (Fig. 14), and in sandy areas near housing tracts that had not been landscaped (Fig. 15). The common denominator seemed to be disturbance that was limited in scope, i.e.,

Figure 12. Dirt track in west Desert Hot Springs, supporting an array of different-aged ASLECO plants growing in a moderately disturbed site.

Figure 13. ASLECO seedlings and first year juveniles along an informal pedestrian walkway in west Desert Hot Springs.

Figure 14. Large ASLEO plants growing and reproducing alongside an auto body shop driveway in rural Desert Hot Springs.

Figure 15. Foreclosed or otherwise unoccupied house with an abandoned front yard used by bicyclists. ASLECO (large plants on the right and lower left) colonized the lot after construction (either from an *in situ* seed bank or via local immigration), and established an active population.

occasional enough to keep substrates loose and open, yet not intense enough to eradicate all seedlings or destroy flowering adults. In other words, to be successful, the disturbance dynamics needed to more or less imitate the natural, wind-aided perturbations the species would have experienced prior to human-imposed habitat alterations.

Conclusions. There is clearly a relationship between ASLECO population maintenance and disturbance, the latter of which may be imitating the natural environmental processes that would have driven milkvetch population dynamics prior to human impacts in the Coachella Valley. The question of interest, then, is whether or not such disturbance is necessary to the survival of the species in the anthropogenic environment it now inhabits. Is it best to try and curtail human disturbances in all ASLECO habitat, or should we encourage limited disturbance? Could we even use focused disturbance as a recovery (or at least population maintenance) tool, perhaps in areas of marginal habitat where the species is now forced to co-exist with urbanization?

The core habitat areas designated under the CVMSHCP, although consisting of the best remaining open areas and habitat corridors, will always suffer from extensive populations of Saharan mustard. The seed bank is in place after a number of successive years of massive and successive infestations throughout the valley and elsewhere in the southern deserts, and there is little hope of reversing this scenario through management. Adapting to the new reality, by working to sustain or create populations within the altered ecosystems, should be the objective. That said, we feel that planned disturbance should play a role in population maintenance for ASLECO. It's difficult to decide what "recovery" would actually mean for this taxon, since it is clear that bringing ASLECO habitat back to a pristine condition (or even close in most cases) is largely impossible. But experimenting with low-level disturbance in selected populations may provide interesting data.

An obvious concern with employing disturbance-related enhancements in plant communities is the potential for increasing weed cover after treatments. In many areas throughout the western U.S., economically driven disturbances such as grazing, mining, and logging have increased weed infestations. Even treatments designed to improve ecological conditions, such as burning, can result in unintentional and dramatic surges in exotic species. In many cases it is better

Figure 16. View of extensive mustard infestations on USFWS refuge lands in 2008.

to forego attempts at habitat manipulations in hopes of restoring sites, and simply work with what you've got.

But then Saharan mustard is already here, and is well entrenched. And while there are a few pockets to the north and east of the valley's urban areas where native plant communities still retain a reasonable degree of integrity, most

ASLECO habitat even outside the cities is already hopelessly inundated with mustard populations. So rather than let ASLECO wink out of its remaining sites as competition increasingly takes it's toll, an alternative might be to implement a more aggressive management program to determine if periodic disturbance in such sites could improve recruitment, despite the toehold exotics already have.

Our observations suggest that the sort of low-impact disturbance that appears to favor ASLECO does not necessarily result in jumps in mustard production—in fact, in microsites such as those along regularly but lightly used sand tracks (see. Fig. 12), ASLECO fared better than Saharan mustard. The opening and shifting of the substrate brought about by intermittent foot and vehicle traffic may mimic the dynamics of open dune crests (see Fig. 2), where ASLECO populations still persist in wind-driven sands even thought the adjacent flats are covered with *Brassica*.

We recommend considering a disturbance program in some of the ASLECO core habitat areas (described in the CVMSHCP) where mustard populations are particularly rampant (see Figs. 16 and 17). It would be interesting to attempt this at selected extant milkvetch sites, where small populations are believed to be declining, as well as in habitat without ASLECO patches, to see if germination and recruitment could be stimulated from the

Figure 17. Mustard levels at the Snow Creek/Windy Point CA, in 2008.

disturbance and temporary removal of mustard. This approach might also provide opportunities for recovery work in unlikely locations. Many areas, including roadsides, golf courses, municipal projects, etc., have open, sandy sites that are regularly disturbed as part of routine maintenance, and which might be compatible with ASLECO, assuming a seed source or greenhouse stock were available for re-introductions. The fact that some of these areas still have tiny remnant populations suggest this could work. While "adopting" an endangered species may not be for everyone, it might be something to think about, policy-wise, especially considering the current state of ASLECO habitat in the various conservation areas identified in the CVMSHCP. At the very least, enlisting Caltrans as a partner should be evaluated—the broad right-of-ways along Interstate 10 in the mid-valley have excellent potential for re-introductions.

We realize that retaining or establishing fragmented, urban patches of a rare species is no substitute for conserving it within habitat corridors, as envisioned in the CVMSHCP, and we aren't advocating this as a solution to the overall problems faced by ASLECO. However, thinking outside the box may be useful here, considering the magnitude of the threat posed by Saharan mustard.

POTENTIAL ECOLOGICAL INTERACTIONS BETWEEN SAHARAN MUSTARD AND ASLECO

Any plans to create new populations of ASLECO or augment existing ones need to take the biology of Saharan mustard into consideration. Clearly, interactions between the two species not only impact extant ASLECO populations, but are a potential hindrance to re-introduction work as well. Information regarding relative germination rates and timing, growth rates, the potential for allelopathic interactions, relative responses to disturbance, and pollinator competition need to be considered.

Germination

ASLECO plants are often highly fecund. However, the number of seeds generated by a single plant varies enormously, with first year annual plants that manage to flower producing only a few dozen seeds, while large, multi-year perennials can disperse thousands. Saharan mustard plants likewise produce many seeds, with larger individuals potentially maturing many thousands, though far fewer are produced by small plants. Although yearly Saharan mustard outbreaks reportedly fluctuate according to annual rainfall amounts, what could only be termed heavy infestations were noted throughout the Coachella Valley every spring during our 5 year investigation, with particularly high production in 2005, 2008, and 2009. The contribution to the mustard seed bank in the valley during these years is impossible to estimate, but conservatively would have to be in the billions. The seed banks of ASLECO and other natives are likely much smaller.

Seeds of ASLECO are extremely hard-coated, typical of legumes, and germinate best if scarified prior to being exposed to wet conditions. They are not innately dormant, though the tight seed coat mostly reduces the potential for germination unless seeds have been nicked or abraded prior to inundation. Although similarly hard-seeded, Saharan mustard seeds will readily germinate without such scarification. They can remain in the seed bank over successive years if not exposed to moisture, but will germinate within a day or two of being soaked. Saharan mustard cotyledons are characteristically bi-lobed, and easily identified (Fig. 18).

Figure 18. Germinating Saharan mustard seedlings at the Coachella Valley National Wildlife Refuge, in early December, 2009.

Observations of germinants and early first year plants at sites near Windy Point, the Coachella Valley National Wildlife Refuge, and in Desert Hot Springs indicate that both species germinate with fall rains, typically in November or December. The number of seedlings observed is correlated with population sizes—correspondingly, most ASLECO populations showed very modest numbers of seedlings even in rainy years (with concentrations highest in disturbed areas), while mustard seedling cohorts in the same areas were enormous, with millions of seeds germinating en masse at many sites. If microsites dried out, as was the case especially in 2006 and 2007, numerous mustard seedlings succumbed before reproducing. However, even in poor precipitation years, enough mustard plants still survived to far outpace the natives, including ASLECO. Since there was considerable niche overlap at many sites, substantially reduced numbers of mustard (as compared to "wet" years) were still adequate to dominate the areas where the two species shared habitat (and this included all the sampling sites we visited during this project).

In 2008, a census we conducted at the Coachella Valley National Wildlife Refuge estimated an average of 3,610 mustard seedlings/m^2 for 10 sample stations, based on ten 1 dm^2 subsamples arbitrarily selected from within a 1m^2 plot frame placed within *Brassica* stands with greater than 75% cover. The 10 sampling stations were a minimum of 50 meters apart. Based on the extensive mustard cover present (see Fig. 16), we estimated that this density was representative of well over a thousand hectares of refuge property that still included a few remnant patches and individuals of ASLECO. Scattered "islands" of steep, wind-blown dunes were the only sites at the refuge that provided a more or less mustard-free zone for ASLECO and other natives. Although most of the mustard plants occurring in such high densities died from self-competition before reproducing, they still exerted competitive influence on other nearby species at the germination and seedling stages before succumbing. It was impossible to estimate the density of ASLECO over the same areas, since milkvetch seedlings were so uncommon—but probably well below 1 seedling per m^2. This situation is believed to be typical for a significant portion of the core habitat areas for ASLECO identified in the CVMSHCP.

Conclusions. Significant competition between ASLECO and Saharan mustard likely occurs at the seedling stage in nature. The two species germinate at more or less the same time, share habitats and microsites, and rely on the same soil moisture and resource pools. There are few areas where ASLECO grows that mustard plants will not thrive. The numbers advantage the mustard has over ASLECO (and all other native herbaceous species) gives it a significant advantage early on. Any attempt to re-introduce ASLECO into wild habitat will need to take into account the high potential for competitive interactions with *Brassica* and other exotic species at the seedling stage.

Growth Rates

After germination, growth rate can be an important indicator of the ability of a species to favorably compete with neighboring plants. ASLECO and Saharan mustard have similar sized seeds (ca. 1 mm) and seedlings, and germinate more or less at the same time in the late fall or early winter. But the biomass produced by the two species over the growing season is dramatically different. Saharan mustard is an obligate annual in the Coachella Valley, while ASLECO is a facultative perennial (it will sometimes overwinter for one or more years in parts of the valley where there is more winter precipitation, such in the Snow Creek/Windy Point CA). After germination, mustard plants rapidly develop a rosette if soil moisture is adequate, and then bolt a few weeks later. ASLECO plants develop much slower, producing a few basal leaves but not a rosette. The milkvetch plants may or may not flower, while mustard plants always do if they don't die prematurely from early season drought.

At the beginning of March, 2008, 26 ASLECO first-year plants (which were non-reproductive and had germinated that winter) and an equal number of young mustard plants were paired in the Snow Creek/Windy Point CA (near Snow Creek Rd.). Late-germinating mustard plants that were ≤15 cm across and still pre-reproductive (or with a flowering stalk less than 5 cm) were chosen for the comparisons. It should be noted that most *Brassica* seedlings are at the rosette stage much earlier, in December or January, but for logistics reasons we were unable to look at growth rates in 2008 until later in the spring. For both species, the height and width of the plant, the number of basal leaves, and the number of flowering stems were measured for each. The measurements were then repeated on the same plants the first week of April.

As expected, mustard plants grew much faster, outstripping ASLECO plants in terms of leave size and number, overall plant width, and number of flowering stalks initiated (Figs. 19 and 20). After ca. 4 weeks, mustard plants had produced 40% more leaves and initiated 10 times as many flowering stems (Fig. 19). The proportional increases for leaf length and plant width (Fig. 20) was more comparable among the sampled plants. However, the most evident between-species difference was in relative bulk, which we couldn't measure since we didn't have a destructive sampling permit for the milkvetch in 2008. Visual estimates suggested that mustard plants put on 8 to 10 times as much biomass over the 4-5 week period.

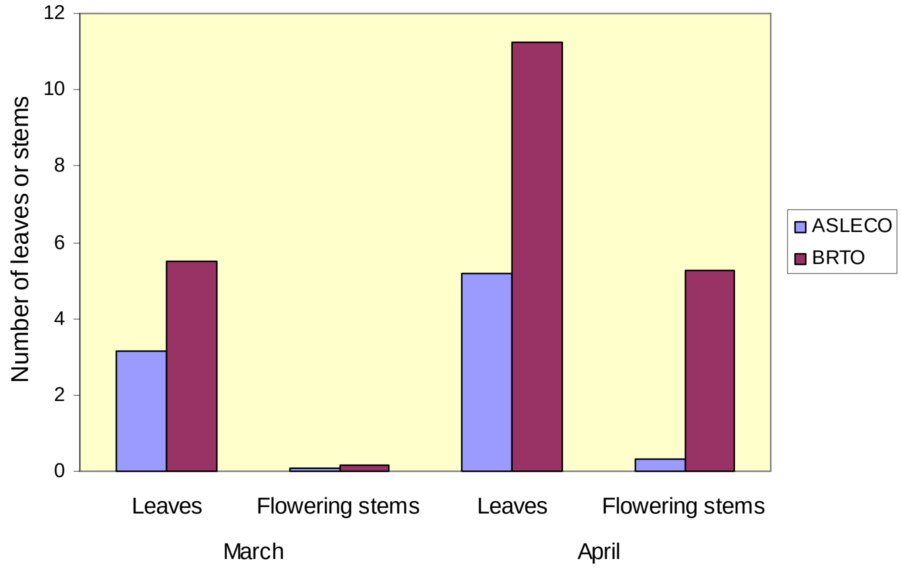

Figure 19. The relative production of leaves and flowering stems by ASLECO and Saharan mustard first-year plants over a 4+ week period in early spring, 2008—see text for details.

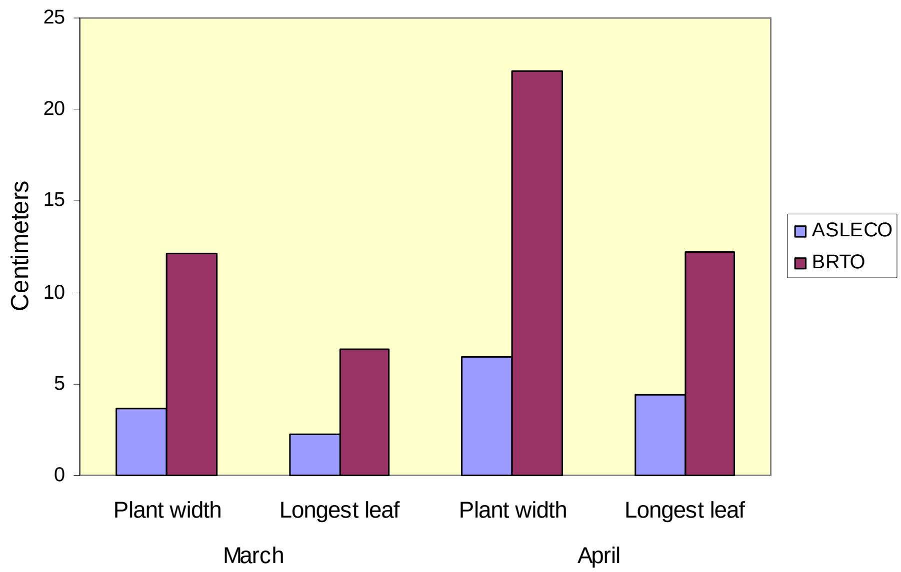

Figure 20. Increases in overall plant width and leaf length (cm) by ASLECO and Saharan mustard first-year plants over a 4+ week period in early spring, 2008—see text for details.

Conclusions. Pre-reproductive Saharan mustard plants are capable of growing faster and to a much greater size than first-year milkvetch plants occupying the same habitat, adding to the tremendous seed bank and germination advantage *Brassica tournefortii* already enjoys. If a mustard plant makes it through the gauntlet of self-competition, the competitive pressure it faces from other species in the Coachella Valley (especially natives) is negligible. This is another factor to consider in any ASLECO recovery planning that includes re-introduction as a component. Experimental removal of mustard plants at the Coachella Valley National Wildlife Refuge has been shown to have a positive (if likely short-term) effect on the survival of native annuals (C. Barrows, pers. comm.), and this, possibly in conjunction with a program to purposely disturb substrates to stimulate ASLECO populations (as discussed previously), may be a prerequisite to successful re-introduction work. The timing of mustard control in a given site would need to be carefully evaluated.

Is allelopathy a potential issue?

Allelopathy is generally defined as the inhibition of growth in one species of plant by chemicals produced by another species. Although not previously reported for *Brassica tournefortii*, considering the near monocultures produced by mustard populations in many areas, we wondered if the species could be chemically suppressing neighboring vegetation. Confirming allelopathic interference by mustard plants could be accomplished by: (a) identifying and describing the symptoms of interference; (b) completing the isolation, assay, characterization, and synthesis of the chemical agent; (c) simulating interspecific interference by supplying the toxin (in a controlled experiment) in a manner consistent with its release in nature; and (d) quantifying the release, movement, and uptake of the toxin, either in the field or cultivation.

A rigorous evaluation of allelopathy in Saharan mustard, as described above, was deemed impractical for this study due to the time and expense required to execute it. However, we did visit many mixed populations of ASLECO and Saharan mustard (primarily the extant populations listed in Table 1, plus several others) to survey for and describe potential symptoms of chemical interference. Although ASLECO density does typically decline as mustard density increases, young plants of the two species commonly grew in close proximity (Fig. 21). Overall, there were no clear symptoms of chemical interference exhibited (such as area-specific ASLECO seedling die-back under mustard canopies, apparent reduction in reproduction or biomass within mustard patches, etc.)—any obvious sign that allelopathy promoted the negative correlation in density between the two species, as opposed to non-chemical exploitative competition for soil nutrients, water, light, or space, was not possible to discern.

In early April, 2008, we measured plant size of ASLECO as a function of their distance from mustard plants at Site nos. 4 and 30 (see Table 1). At each site, a 100 m tape was used to set up a transect through an ASLECO population that was overtopped by heavy patches of mustard (these were mixed stands of ca. 60-100% cover, interspersed with scattered open ground). For each first-year milkvetch plant encountered within 5 m to either side of the tape, the mean distance from the plant to the base of the closest three mustard plants was calculated. Then, for each ASLECO plant, a size index was calculated, i.e. (width of plant in cm)*(number of leaves present). The distance measure was then plotted as a function of plant size (see Fig. 22). Being closer to mustard plants appeared to have no detrimental effect in terms of plant size in ASLECO. In fact, there was a slight negative correlation, where the larger milkvetch plants actually tended to occur closer to the mustard plants, possibly because the microsites that favored mustard (as related to nutrients, soil moisture, etc.) may also have favored ASLECO. In any case, allelopathic impacts on plant size were not evident.

Figure 21. First year ASLECO plants (that had germinated only weeks earlier) commonly grew in close proximity to actively growing mustard plants, suggesting a lack of allelopathic interference between juvenile plants of the two species—it is unknown if seedlings react similarly.

Conclusions. We found no evidence of an allelopathic interaction between ASLECO and Saharan mustard, at least for first year milkvetch plants. However, our conclusions are based on field observations and not experimentation or lab analyses, and there are various life history stages where allelopathy could be manifested, including germination and seedling establishment. Further investigation is needed before ruling allelopathy out as a potentially significant interference between the two species.

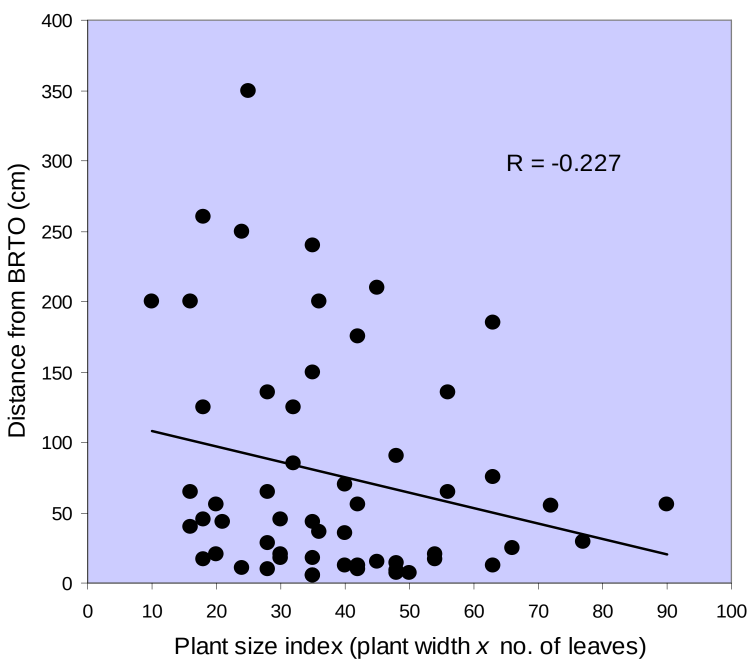

Figure 22. The distance ALESCO plants grew from the base of mustard plants as a function of plant vigor in ASLECO (measured by a size index)—see text for further explanation.

Pollinator competition and competition for pollination

Our earlier work, in 2005 and 2006, revealed that honeybees were far and away the dominant floral visitor to ASLECO plants. In 2008, we completed additional pollinator observations (on March 4th and 5th, and April 8th, 10th, and 29th) to confirm our previous observations. Two to three hours of reconnaissance were completed each day, and included surveys of populations near Snow Creek Rd., Windy Point, Garnet Station, along Gene Autry Trail and Bob Hope Dr., and at the Coachella Valley National Wildlife Refuge. Windy days often limited observations, but of the 585 pollinator visits that were recorded, only three were not by honeybees. One was a *Bombus*, and the other two were potentially a *Megachile* sp. All three were observed on an open dune at the refuge. So as far as *pollinator* competition for ASLECO floral resources goes, that battle appears to have been fought and lost by the native bees some time ago. Indigenous bees are uncommon to non-existent on most native plants in the urbanized parts of the valley today, even in the colorful vacant lot patches of native wildflowers, where concentrations of *Abronia*, *Camissonia*, and *Oenothera* dominate (along with Saharan mustard).

But despite the problems facing the native bees, milkvetch plants have little trouble producing seed, and plants (particularly in the northern portion of the valley) are often heavily laden with fruit and viable seeds throughout late winter and spring (Fig. 23). So if there is any reproductive impact to ASLECO from a reduction in native pollinators, it is not apparent. And considering the high levels of milkvetch seed set widely observed over the course of this study, it

Figure 23. Heavy fruit production observed on ASLECO plants near the Palm Springs Amtrak station in 2009.

also appears unlikely there is any significant impact to pollination or seed production in ASLECO as a result of *competition for pollination with other plant species*, most notably Saharan mustard. Although *Brassica* flowers are likewise (very successfully) pollinated by honeybees, based on our observations, there appear to be enough bees to go around at this point, and seed set in both species remains high even in areas dominated by mustard populations.

Conclusions. Competition with Saharan mustard and other weeds for water and soil resources is a formidable issue for most ASLECO populations, but competition for pollinator services is not. Milkvetch plants produce large amounts of outcrossed seed in many areas (generally on a gradient across the valley, with higher production to the northwest and less to the southeast, based largely on the propensity of plants in a given area to perennate or not). It would be interesting to see how the local bee fauna responds if restoration efforts, including surface scarification and/or mustard removal, were implemented in earnest.

CAN ASLECO BE SUCCESSFULLY CULTIVATED FOR OUTPLANTING WORK?

Yes. Although there was no point in attempting to mass cultivate the species during this study, we have been able to grow healthy ASLECO plants to a size that would be suitable for outplanting in the field for potential re-introduction work (Fig. 24). Seeds are plentifully produced in nature and are

Figure 24. ASLECO growing in outdoor bed near greenhouses at Oregon State University (photo by Brian Knaus).

easy to germinate once scarified, and plants can then be grown to maturity in well-drained media (avoid using sand only, since this has a tendency to turn to "cement" in pots after repeated waterings and drying in pots). Plants could be grown in plastic pots or flats, and experimentation would be needed to determine the optimal plant size for outplanting. Plants grow rapidly if kept warm and well-watered (reaching 10-20 cm across in 3-4 months), and unlike other *Astragalus* we have worked with, grew vigorously without any mycorrhizal inoculation. If we can grow ASLECO in Corvallis, Oregon, it would likely be even easier to accomplish in a nursery setting in the Coachella Valley.