LEAD AGENCY

Lake Mead National Recreation Area, National Park Service

Featured Project

Control of Sahara Mustard, *Brassica tournefortii*, In Rare Plant Habitats

Project Description

The goal of this project was to initiate and expand control efforts for *Brassica tournefortii* (Sahara mustard) invasions on high priority rare plant habitats within Clark County. The objective was to provide emergency conservation actions to protect sand-loving rare plants. The index of success was the removal or destruction of a significant portion of Sahara mustard plants from rare plant, sandy habitats over a two year period.

Fig. 1. Sahara mustard infestation.

Project Status

This two year emergency control effort for Sahara mustard has been completed (Contract reference: CBE NO.5529-04). This document represents the final report for work performed by the National Park Service, Lake Mead National Recreation Area, with funding primarily received from the Clark County Multiple Species Habitat Conservation Plan during the 2004 and 2005 field seasons.

Fig. 2. Removal effort for Sahara mustard.

Partners

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Funding Awarded

$59,000

Funding Spent

$59,000

Completion Date or Status

Project Completed, 15 August 2005.

Products Produced from Project

This project constituted conservation actions for emergency control of *Brassica tournefortii* (Sahara Mustard) within high priority rare plant habitats in Clark County. Over the two year period of this project, 3,313,076 Sahara mustard plants were removed or destroyed within, or adjacent to, targeted sandy habitats.

CONTROL OF SAHARA MUSTARD, *Brassica tournefortii*, IN RARE PLANT HABITATS

FINAL REPORT (Contract reference: CBE NO.5529-04)
Work performed by the National Park Service, Lake Mead National Recreation Area during the 2004 and 2005 field seasons with emergency funding primarily received from the Clark County Multiple Species Habitat Conservation Plan

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INTRODUCTION

Invasive species are often cited as ranking second only to habitat loss as a threat to biodiversity (Wilcove et al. 1998; Levine et al. 2003; Thompson 2005). The term invasive species has been defined as a species that demonstrates rapid growth and spread, invades habitats, and displaces other species (Melvin 1999). Plants that are prolific seed producers, have high seed germination rates, and/or rapidly mature, are predisposed to be invasive (Melvin 1999). For many rare and endemic plants, preventing and controlling the impacts of invasive non-native plants is increasingly a management priority (Oostermeijer 2003; Thompson 2005). There have been many documented plant invaders into the eastern Mojave Desert; however, until recently the sand dunes habitats, home to several endemic plant species, have been relatively free from the negative impacts associated with such invasions. *Brassica tournefortii* (Sahara mustard, also called Tourneforts birdrape, Moroccan mustard, or African mustard) has invaded the Mojave Desert and has since spread quickly (Fig. 3). Sahara mustard is native to marine beaches and sand dunes of the Mediterranean (Thanos, et al. 1991), and has demonstrated many invasive qualities, particularly within sandy habitats. This plant, along with *Schismus arabicus,* and *S. barbatus* (Mediterranean grasses) appear to pose the biggest risk to native sand-loving plants within southern Nevada.

Sahara mustard was recently rated by the California Exotic Pest Plant Council (CalEPPC 1999) as a regional pest. It has also been noted as an invasive plant of concern (Bossard, et al. 2000). This early winter annual has a wide tolerance for multiple habitats and environments, and disturbed areas are no longer the only sites where Sahara mustard has been found. Within Lake Mead National Recreation Area (LMNRA) it has been documented from a range of substrate types including sandy beaches, gravelly washes, roadsides, limestone, desert pavement, gypsum and even in the leaf litter of *Tamarix ramosissima* (D. Bangle, personal observation). Sahara mustard is taller than many native annuals, germinates earlier, has rapid individual growth, produces an enormous amount of seed, can achieve extremely high densities, and appears capable of shading out or crowding out native annuals (E. Powell and D. Bangle, unpublished report).

The wide ranging and potentially cascading effects of a widespread invasion of Sahara mustard is not known, however it may suppress native annuals and alter fire frequency by increasing fuel loads (Brossard, et al. 2000). The rapid spread of Sahara mustard has raised serious concerns regarding native plants, as well as the natural

functioning of desert ecosystems. This species is becoming widespread and out-of-control in some areas of the Mojave Desert (See Fig. 4), and has moved from the status of an emerging threat to a weed of real significance.

Sahara mustard was first collected and identified within LMNRA in the spring of 1997 and its distribution was noted as occasional (J. Alexander, collection notes). In subsequent years, Sahara mustard was observed in many locations throughout the park including rare plant habitats. In the winter of 2003-2004, the Weed Sentry crew documented the widespread distribution of Sahara mustard within Clark County. Throughout LMNRA, and surrounding areas, sand dunes and washes appeared to be particularly favored invasion sites by Sahara mustard.

The potentially damaging effects of Sahara mustard lead to the request for emergency funds to initiate control efforts in rare and endemic plant habitats within Clark County. Funds were acquired from the Clark County Multiple Species Habitat Conservation Plan (MSHCP) and augmented with money from the National Park Service (NPS) through grants from the Department of Interior Cost Share Initiative and the Conservation Challenge Initiative. The goal and objective of this project, as stated in the MSHCP proposal, was to treat incipient populations of Sahara mustard in high priority sandy habitats within Clark County in an effort to conserve rare plant species. The focus of mitigation was rare and endemic plant habitats particularly within sandy or well-drained soils. The native plant species of greatest conservation concern were:

- Threecorner milkvetch, *Astragalus geyeri* var. *triquetrus* (MSHCP Covered, Nevada State Listed Critically Endangered);
- Sticky buckwheat, *Eriogonum viscidulum* (MSHCP Covered, Nevada State Listed Critically Endangered);
- Pahrump Valley buckwheat, *Eriogonum bifurcatum* (MSHCP Covered);
- White-margined beardtongue, *Penstemon albomarginatus* (MSHCP Covered);
- Yellow two tone beardtongue, *Penstemon bicolor* ssp. *bicolor* (MSHCP Evaluation);
- Mokiak milkvetch, *Astragalus mokiacensis* (MSHCP Evaluation);
- Amargosa beardtongue, *Penstemon fructiformis* ssp. *amargosae* (MSHCP Evaluation);
- Rosy two tone beardtongue, *Penstemon bicolor* ssp. *Roseus* (MSHCP Watch);
- Beaver Dam breadroot, *Pediomelum castoreum* (MSHCP Watch).

The two species of Nevada State Listed Critically Endangered plants were endemic to sand dunes of the Virgin and Colorado rivers drainages and on sand dune systems (e.g. Sandy Cove) within LMNRA. These areas had all been invaded by Sahara mustard. These plants appeared to be most immediately threatened by even localized invasions of Sahara mustard. Given that Sahara mustard was widely distributed and widespread throughout the county, only areas potentially containing rare and endemic sand-loving plants and sand dune systems contained within intensively managed areas (IMA) were considered for control efforts.

GOALS AND DELIVERABLES

The proposal listed several geographic areas as focal points for Sahara mustard control efforts. These areas were identified as containing rare and endemic plants found in sandy habitats within intensively managed areas. The general areas identified (along with the land owner and species of focus) included:

- Sandy Cove, LMNRA, site of three-corner milkvetch (*Astragalus geyeri* var. *triquetrus)*;
- Virgin River Dunes, LMNRA and BLM, sites of threecorner milkvetch, sticky buckwheat (*Eriogonum viscidulum)*, and Beaver Dam breadroot (*Pediomelum castoreum)*, as well as other uncommon sand-loving species;
- Jean Dry Lake, Hidden Valley, and Ivanpah Valley, BLM, habitat sites for populations of white-margined Penstemon (*Penstemon albomarginatus)*;
- Sandy areas within the Muddy River Drainage, BLM, important habitats for threecorner milkvetch and Beaver Dam breadroot.
- Sandy areas within the Logandale Trails area, BLM, important habitat for threecorner milkvetch and Beaver Dam breadroot.
- Sandy/Saline areas in Pahrump Valley and Sandy Valley, BLM, habitat for Pahrump Valley buckwheat (*Eriogonum bifurcatum)*.

Three specific deliverables were defined:

1. Spring 2004: Removal of a significant portion of Sahara mustard from specific rare plant habitats on Sandy Cove, Virgin River Dunes, and in Jean Dry Lake.
2. Spring 2004: Survey of specific rare plant habitat in sandy areas in Muddy River drainage, Logandale Management Area, Pahrump Valley and Sandy Valley.
3. Spring 2005: Depending on rainfall and infestation sizes, removal of significant portion of Sahara mustard from specific rare plant habitats on Sandy Cove, Virgin River Dunes, Jean Dry Lake, Muddy River drainage, Logandale Management Area, Pahrump Valley and Sandy Valley.

Surveys for Sahara mustard in identified rare plant habitats were conducted by UNLV employees working with the NPS Resource Management staff at LMNRA on the Weed Sentry Program and rare plant inventory and monitoring. The perimeter of areas and access roads were all surveyed from vehicles and certain areas were surveyed in greater detail by canvassing on foot. A previous survey by Niles et al. (1995) that documented the occurrence and distribution of *Astragalus geyeri var. Triquetrus* and *Eriogonum viscidulum* was used as a guide to find populations of these rare plants within the areas of heavy infestation.

The proposal called for the creation of a '*Brassica* crew' to conduct field activities. Training of the field crews and coordination of the project was provided by members of the Weed Sentry crew and rare plant monitoring and inventory personnel, LMNRA. During the initial field season (2003-2004), Nevada Conservation Corp. (NCC) personnel were hired for field activities. The use of NCC personnel was necessary because of the urgent need for early season control of this annual plant. During the 2005 season (winter 2004–spring 2005), a crew of four was assembled from personnel hired

through the Student Conservation Association (SCA) and UNLV. Early germination of Sahara mustard brought on by record winter rains and cool temperatures required early efforts at control. Field efforts began in early November (2004) and continued through May (2005). The Weed Sentry crew was used for control work early in the season. The *Brassica* crew leader was hired in December (2004) and worked closely with Weed Sentry personnel, but the rest of the *Brassica* crew was not available until the middle of February (2005). NCC personnel were used on several occasions to supplement the field crews and expand their capabilities.

Most of the fieldwork consisted of mechanical removal, which was proven effective in prior years at LMNRA (Fig. 2 & 5). Mechanical removal methods were thought to be the least damaging to the environment and were selected as standard operating procedure throughout the 2003-2005 field seasons. In rare plant habitats, the use of herbicides was not considered prudent predominately because of concerns that the application may kill non-target plants. Sahara mustard was easily killed by mechanical uprooting either with a hula-hoe when plants were in a rosette stage or by hand pulling larger plants. Early in the season, non-fruiting plants were left on site to desiccate. Later, fruiting plants were pulled and placed in heavy black plastic bags for removal from site. Plants were double or triple bagged as necessary to help prevent seeds from spilling.

Areas that had heavy Sahara mustard infestations were first surveyed for species of concern. When a rare plant was located, a 50-foot perimeter surrounding the plant(s) was targeted for clearing to provide a buffer zone. This strategy was implemented at certain sites because the infestations were so heavy that complete removal efforts were not practical given time and personnel. In areas of light infestations, the goal was to eradicate all Sahara mustard within the immediate vicinity of rare plants and their habitat. These efforts were considered stop-gap measures. Long term, region wide strategies for the preservation of rare plants and habitats will need to be developed in consultation with various stake holders.

ACHIEVEMENTS AND LEVELS OF PERFORMANCE

Sahara mustard removal efforts within rare plant habitats were substantial in both 2004 and 2005 seasons (Table 1). A total of 1,778,896 plants in 2004 and 1,534,180 plants in 2005 were destroyed within priority habitats. Rough approximations of the number of person-days committed to field efforts for these removals, including search times, were 437 and 752 for 2004 and 2005, respectively. The following provides a performance summary of Sahara mustard control efforts listed by area of concern.

Sandy Cove

Sandy Cove is an active sand dune system completely contained within LMNRA. A total of 59,832 Sahara mustard plants were removed or destroyed on Sandy Cove dunes and beaches during the 2004 season (Map 1). Field efforts consisted of intensive search and destroy operations where the dunes were visited several times throughout the season. The control efforts for Sahara mustard at Sandy Cove were expanded to surrounding beaches and areas with high infestations. These areas included: shoreline beaches directly across the lake, the Boulder Beach area, Government Wash area, Gypsum Wash, Eight-O shoreline, Boxcar and Crawdad Coves, Callville Bay, and the adjacent beaches of Hamblin Bay. These beaches and infested shoreline areas were

thought to be potential reintroduction sources for Sandy Cove. Sahara mustard removals from these sites yielded another 1,556,621 plants.

In 2005, the amount of Sahara mustard on Sandy Cove was immense and control efforts in this area focused on the dunes and the directly associated beaches (Map 2). A total of 297,696 plants were removed. Sahara mustard was not completely eradicated from the dunes. Steep sandy slopes were difficult to access and these were generally not treated. These steep areas are likely to re-infest the dunes until effective treatment methods are developed for these slopes.

Table 1. Number of *Brassica tournefortii* removed from priority areas by contributing entities.

Year	Contributor	Plants Removed
2004	*Brassica* Crew (NCC)	1,387,256
	Weed Sentry Crew	275,426
	NPS In Kind Contributions	116,214
	Total	1,778,896
2005	*Brassica* Crew with NCC	1,104,045
	Weed Sentry Crew	240,913
	NPS In Kind Contributions	183,472
	Volunteer Contributions	5,750
	Total	1,534,180
	Grand Total	3,313,076

Jean Dry Lake, Hidden Valley and south into the Roach Valley

Jean Dry Lake, Hidden Valley and areas of Roach Valley contain critical habitat for *Penstemon albomarginatus*. Surveys of *P. albomarginatus* habitat within the Jean Dry Lake area during 2004 revealed no Sahara mustard. Surveys during 2005 yielded two Sahara mustard infestations that were directly in, or next to, *P. albomarginatus* colonies (Map 3). One infestation of 3,077 plants was immediately removed. The other infestation was along a road and spaced out over approximately 1.5 miles. This population was not treated at the time because the infestation was too much for the staff on hand and because the plants were reaching maturity and seed drop was imminent. This infestation should be prioritized for treatment in coming years. The habitats of *P. albomarginatus* should be a high priority for future control efforts because the light infection of Sahara mustard provides the opportunity to keep this plant from spreading throughout this area.

Logandale Trails, Muddy River Drainage and the Virgin River Dunes

The Logandale trails system, Muddy River drainage and the Virgin River Dunes are all part of a connected system in and around the Mormon Mesa (Map 4). Collectively, these areas may support the worst infestations of Sahara mustard within Clark County. Treatment efforts in 2004 focused within the area of the Virgin River Dunes where 10,062 plants were mechanically removed. Work started inside LMNRA and moved north onto BLM lands along the road at the base of Mormon Mesa (Map 5).

Plants were removed by nine people spaced out approximately 100 meters on either side of the road.

The 2005 survey within the LMNRA portion of the dunes was not completed because of an un-cooperative private land owner whose 40 acre parcel of land blocked access to NPS approved road 112a (currently the only means of accessing the area). Only 25 Sahara mustard plants were found and removed from the LMNRA surveyed portion of the dunes in 2005. The issue of access should be resolved by the spring of 2006 and both the BLM and NPS portions of the dunes are on the priority list for future control efforts.

In 2005, the I-15 corridor from the junction of highway 93 north to Moapa was heavily infested, but patchy. The I-15 corridor from Moapa north to Mesquite was dominated by Sahara mustard with an almost continuous distribution. The infestation at the Carp/Elgin exit road (Exit 100) extended from I-15 to approximately 1mile north into the surrounding desert. Many of the large drainages within this area are habitat for *Astragalus geyeri, Eriogonum visidulum,* and *Pediomelum castoreum* (including Toquap, Halfway, and Wieser washes). These drainages have been extensively invaded by Sahara mustard.

Treatments during 2005 in some areas were guided by previously reported locations for *Astragalus geyeri* and *Eriogonum viscidulum* (Niles et al. 1995). Toquop Wash had two locations with rare plants identified and 6,578 Sahara mustard plants were removed from the surrounding areas. Weiser Wash had three rare plant locations identified and 9,212 Sahara mustard plants were pulled and removed from this area. At the Carp/Elgin turnoff an additional four sites were identified and 4,020 Sahara mustard plants were pulled.

Pahrump Valley and Sandy Valley

Pahrump Valley and Sandy Valley contain populations of *Eriogonum bifurcatum.* During 2005, no infestations of Sahara mustard were documented. Not finding Sahara mustard during a particularly wet year when seeds should have germinated and produced plants was significant. The lack of observed Sahara mustard plants in these areas allows for the adoption of a zero tolerance strategy for future control efforts.

Additional Areas

Several additional areas were surveyed and treated during spring of 2005, but were not listed within the original set of deliverables. These areas were included and made possible by the contributing funds of the NPS. These sites included:

1. The Overton Arm area of Lake Mead, which supports populations of *Eriogonum viscidulum*. Within this area, 547 Sahara mustard plants were destroyed. Eradication was attempted but not completed because of time restraints.
2. Sandy Point within LMNRA supports *Pediomelum castoreum*. Within this site, 832 Sahara mustard plants were destroyed. Eradication was attempted but not completed because of time restraints.
3. Several hot spots of Sahara mustard were identified along the Valley of Fire and Bittersprings roads within LMNRA and sections were cleared. In total, 77,264 plants were removed from these areas; however a large section along the Valley of Fire Road was not treated.
4. An area of high plant diversity within the Newberry Mountains, LMNRA and BLM, was treated during both field seasons with 19,786 plants removed during

2004 and 39,024 plants pulled in 2005. This effort was directed for total removal of Sahara mustard within sight of the entire length of Christmas Tree Pass Road.

5. Various areas throughout LMNRA that had high potential for vectoring infestations were also treated. Sites treated in 2004 and/or 2005 included, areas along Northshore Road, Lakeshore Road, Willow Beach, Temple Bar area, Katharine's Landing, Echo bay, Overton Beach, and certain backcountry roads. The total number of *Brassica tournefortii* removed from these areas for both years was 1,228,227.

CHALLENGES AND LESSONS

Control of Sahara mustard within critical habitats appears vital. If left alone it can dominate sandy habitats and possibly out-compete native plants. Once Sahara mustard has established on a site, control efforts could take years of removals to exhaust the seed bank if possible at all. Any missed plants could spread seeds over large areas. This is especially true in sandy habitats because the seeds are constantly moving with the shifting sands, therefore, not all seeds within the seed bank are at a depth suitable for germination at any one time. This implies that even in a record high rainfall year when many seeds within the 'germination zone' are expected to produce plants, there will likely be remaining seeds at greater depths within the shifting sand. This process was exemplified by our control efforts at Sandy Cove (Fig. 6). Sandy Cove is habitat for one of the largest known populations of *A. geyeri*, which during 2005 reached a record number of individuals. This abundance was likely the result of record rainfall, but the intense Sahara mustard control efforts since 2001 may also have been a contributing factor. The goal at this site had been the complete elimination of Sahara mustard, although this goal now appears untenable. The high rainfall in 2005 produced an abundance of Sahara mustard plants on Sandy Cove in spite of previous control efforts (Fig. 7). Apparently, some level of control will likely be necessary for the indefinite future.

Our attempts at controlling Sahara mustard in the Mormon Mesa area (especially Carp-Elgin, Toquop Wash, Weiser Wash areas) were not highly successful. No real control efforts were conducted in these areas prior to the initiation of the current effort. Likely, Sahara mustard seeds have been accumulated for a number of years within the soils of these areas from low level infestations of plants. The increased rainfall of the 2005 season allowed for a massive production of Sahara mustard plants which overwhelmed our control efforts. The control efforts, however, were not without affect on a small scale in that numerous, individual rare plants had areas around them cleared of Sahara mustard. A more aggressive approach to these areas will likely be required to conserve rare plants. Infestation of Sahara mustard within a perimeter of the rare plant habitat should be targeted for clearing, not just around individual plants.

IMPACT

The index of success for this project was that a significant portion of Sahara mustard would be removed from high priority rare plant habitats in Clark County during the 2004 and 2005 field seasons. The focus was on a series of high priority sandy habitats. Although large numbers of these plants were removed (Table 1), we recognize that our ultimate success was mixed. Within the Jean Dry Lake area, the early detection and elimination of small satellite populations of Sahara mustard may have greatly slowed the infestation within *P. albomarginatus* habitats. In these areas, Sahara mustard does not appear to have become well established, and our control efforts may have been highly successful. Of mixed success have been our efforts at Sandy Cove, where a large amount of resources have been invested in an attempt to eliminate all Sahara mustard and to deplete the seed bank. After our experience with the 2005 field season, the goal of complete elimination of Sahara mustard appears untenable at any site where this invasive plant has become well established or where there are nearby established infestations that can act as source populations for new infestations. Nevertheless, our control efforts appear to have kept Sahara mustard from dominating the dune system. A more realistic goal on high priority sandy sites, like Sandy Cove, may be to attempt to contain infestations at very low levels through annual efforts. Control efforts to eliminate substantial amounts of Sahara mustard at these sites appears necessary and would need to be particularly extensive during years of high Sahara mustard production. The unacceptable alternative would be to allow Sahara mustard to dominate within sandy habitats and out-compete native annuals. Finally, extensive Sahara mustard infestations overwhelmed control efforts in rare plant habitats within the extended area around Mormon Mesa. These areas are habitat for several species of concern and an aggressive integrated management approach will need to be adopted if rare plant habitats in these areas are to be conserved.

RECOMMENDATIONS

Sahara mustard has become a threat of real significance to rare and endemic plants within sandy habitats of southern Nevada. An aggressive approach to managing Sahara mustard is necessary for protecting species of concern. Two general management actions are implicated from our experience with attempted control of this weed. First, early detection and elimination of new infestations within or near critical habitats, as well as eliminating outlying colonies at the edges of areas already infested, appears to be a good strategy for slowing the spread of this invasive plant into rare plant habitats. Second, control effort needs to be aggressively expanded and maintained to reduce population densities of Sahara mustard within critical habitats if these controls are to have meaningful positive effects on rare and endemic plants. In addition to these general observations, we make the following specific recommendations.

The *Brassica* crew could increase its efficiency by employing a long term/permanent position seasonally dedicated to managing Sahara mustard control efforts. The individual would be responsible for training and leading crews, assuring that priority areas are treated, coordinating an expanded volunteer program (see below), and developing networks with regional professionals, entities, and agencies. This individual

would also be critical for coordinated control efforts between land management agencies, especially within border areas between various land owners.

Potential sources for short-term personnel that can be hired seasonally for control efforts are: NCC, American Conservation Experience (ACE), Nevada Division of Forestry (NDF), and SCA. One potential problem with some of these organizations is that they employ mostly college students and recent graduates, some of whom are unavailable early in the year when control efforts are most effective. The Weed Sentry crew and personnel from the rare and native plant program could be used to support *Brassica* crews, especially in identifying areas for treatment, but these personnel are funded for other projects and their focus on those projects needs to be maintained,

At LMNRA, a volunteer program called the "Mustard Buster" was initiated in 2004. This program provided interested parties with an explanation of the importance of Sahara mustard control and training in the identification of Sahara mustard and similar-appearing native plants, control methods, and safety issues. Only after an individual had received this training were they permitted to remove Sahara mustard within LMNRA. This concept has the potential for expansion and provides land managers with access to a potentially large labor force. It rewards volunteers with the feeling of contributing to efforts at protecting and preserving public lands and natural resources. An expanded volunteer program could work like a site steward program where specific groups of volunteers (e.g. various organizations) would be responsible for removing Sahara mustard from their chosen areas each year after which they would report what they achieved to a volunteer coordinator. Additional volunteer crews could be formed to provide the *Brassica* crew with targeted assistance. For instance, student volunteers could be recruited to remove Sahara mustard on a designated weekend, possibly as part of an integrated curriculum. Students could get a lesson in conservation biology with an emphasis on invasive species and a real feel for the challenges faced by land managers. The development and organization of an expanded volunteer program would be a major responsibility for the *Brassica* crew leader, and the program is ideally suited for the Interagency Volunteer Program coordinated by the Public Lands Institute at UNLV.

Control efforts for Sahara mustard are most efficient early in the phenology of the plants while plants are still rosettes and can simply be uprooted without the need for time consuming bagging and removal. This time period for efficient control will depend on rainfall and temperatures. Multiple major rain events over time can trigger multiple germination events. During most years, a probable early 'window of opportunity' is available. An effective strategy would be to employ as many crews (volunteer and hired) as possible early in the season to take advantage of this efficiency window. These crews will treat designated priority areas (rare plant sites and areas known to re-introduce Sahara mustard to those rare plant sites). In general, the period of January through March, while plants are in the rosette stage, should be targeted for large-scale control efforts. Removal efforts could continue into May in priority areas, although plants would need to be bagged and removed. Variability in the timing and amount of desert rainfall, however, requires organizational and budgetary flexibility. Large crews must be available early in some years (e.g. high rainfall years) and may not be useful during severe drought years. Monitoring and coordination early in the season, as well as flexibility in the hiring of field crews, is required (this is a further argument for a team leader on Sahara mustard control).

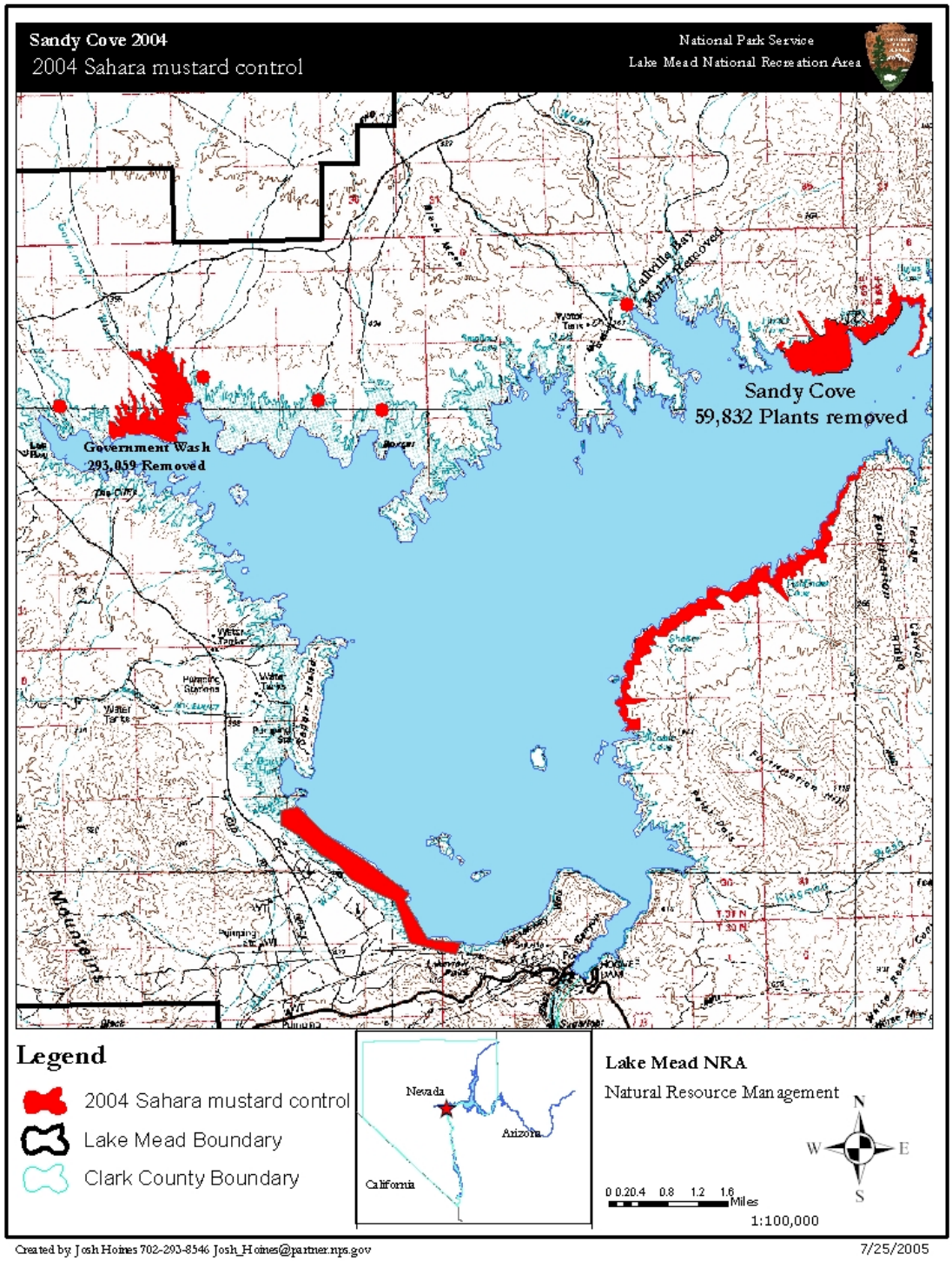
Surveys of rare plant habitats should be expanded to document the status of native plants and provide for the presence or absence of Sahara mustard. Many rare plant sites

have not been visited for years, and following the massive production of Sahara mustard in 2005 some evaluation of previously known sites should be attempted. These surveys could be used to help organizing and prioritizing Sahara mustard control efforts during the next couple years.

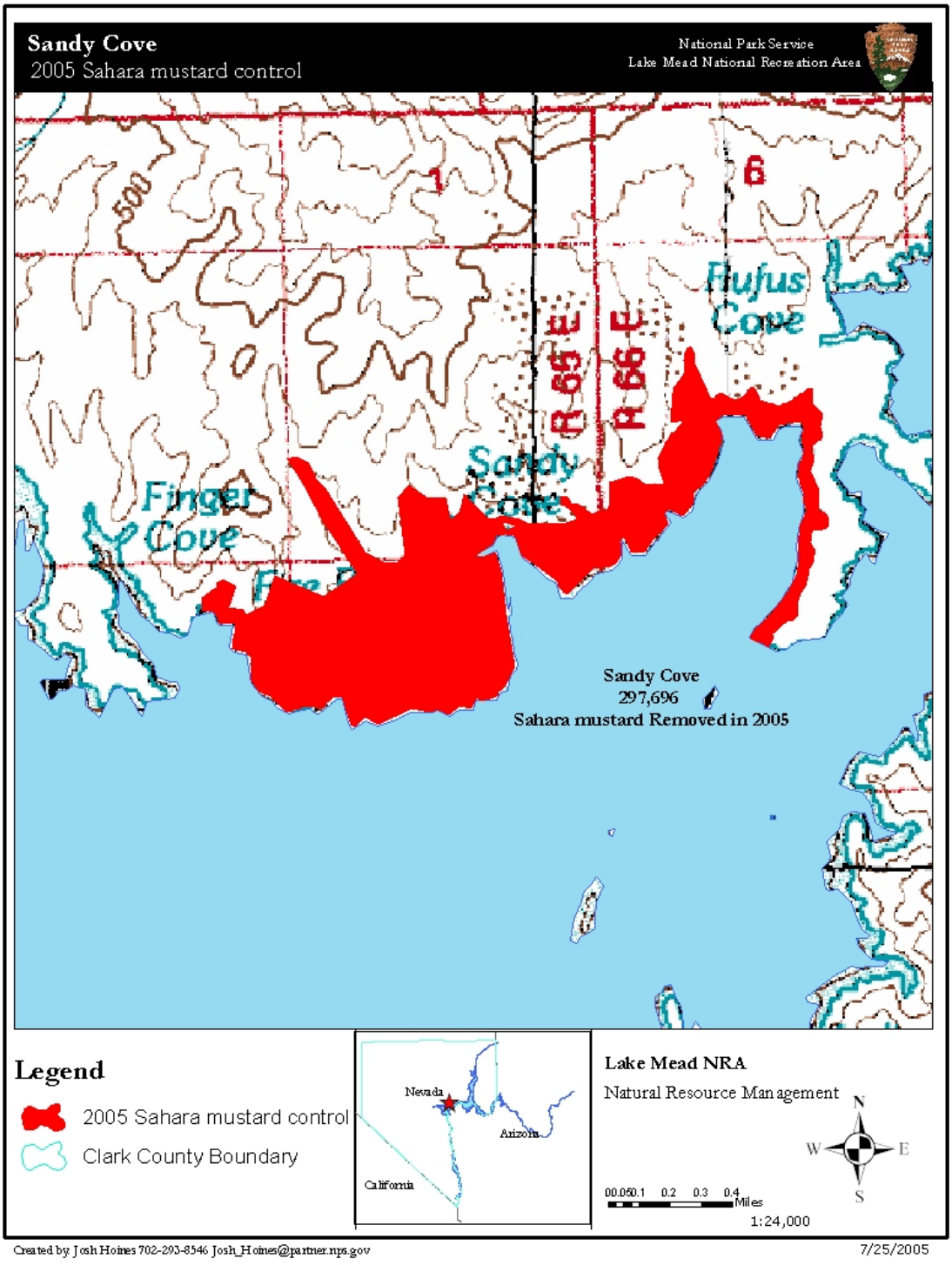
Finally, several areas of research are critically required to develop an effective management strategy for Sahara mustard in rare plant habitats. We support research, some of which has already been funded for the next biennium under NPS and USGS proposals, which will help develop effective management strategies for Sahara mustard. Research on herbicide treatments is critically needed to develop an integrated pest management strategy. Concerns on the application method for herbicides within rare plant habitats (sprays may drift during application) and on undesirable persistence within soils need to be addressed. Nonetheless, herbicide treatments under some conditions and in some areas may be an efficient and effective tool for control efforts, particularly for creating buffer zones around critical habitats.

Specific recommendations have already been made to conduct research to determine the stage of development that un-ripened seedpods can be left in the field without becoming viable. This research has the potential to extend the length of time crews can drop plants on site instead of conducting the time consuming task of bagging and removal. Finally, the long-term effectiveness and impact of site-specific control efforts for Sahara mustard on the conservation of rare plants is unknown. We support proposals for the development of long-term control plots, with replication, within critical habitats that could be used to evaluate the effectiveness of various control efforts.

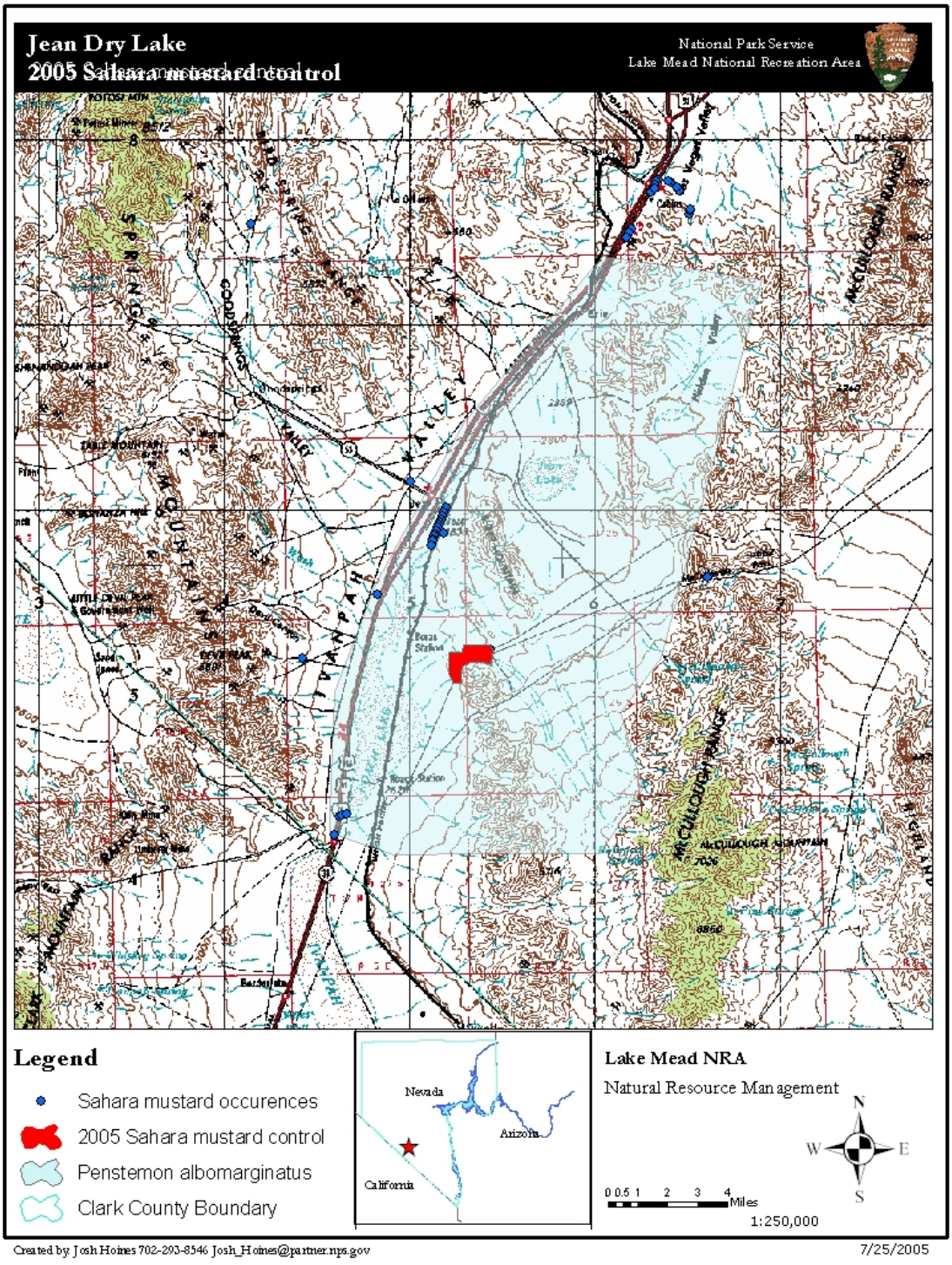
EVIDENCE OF RESULTS



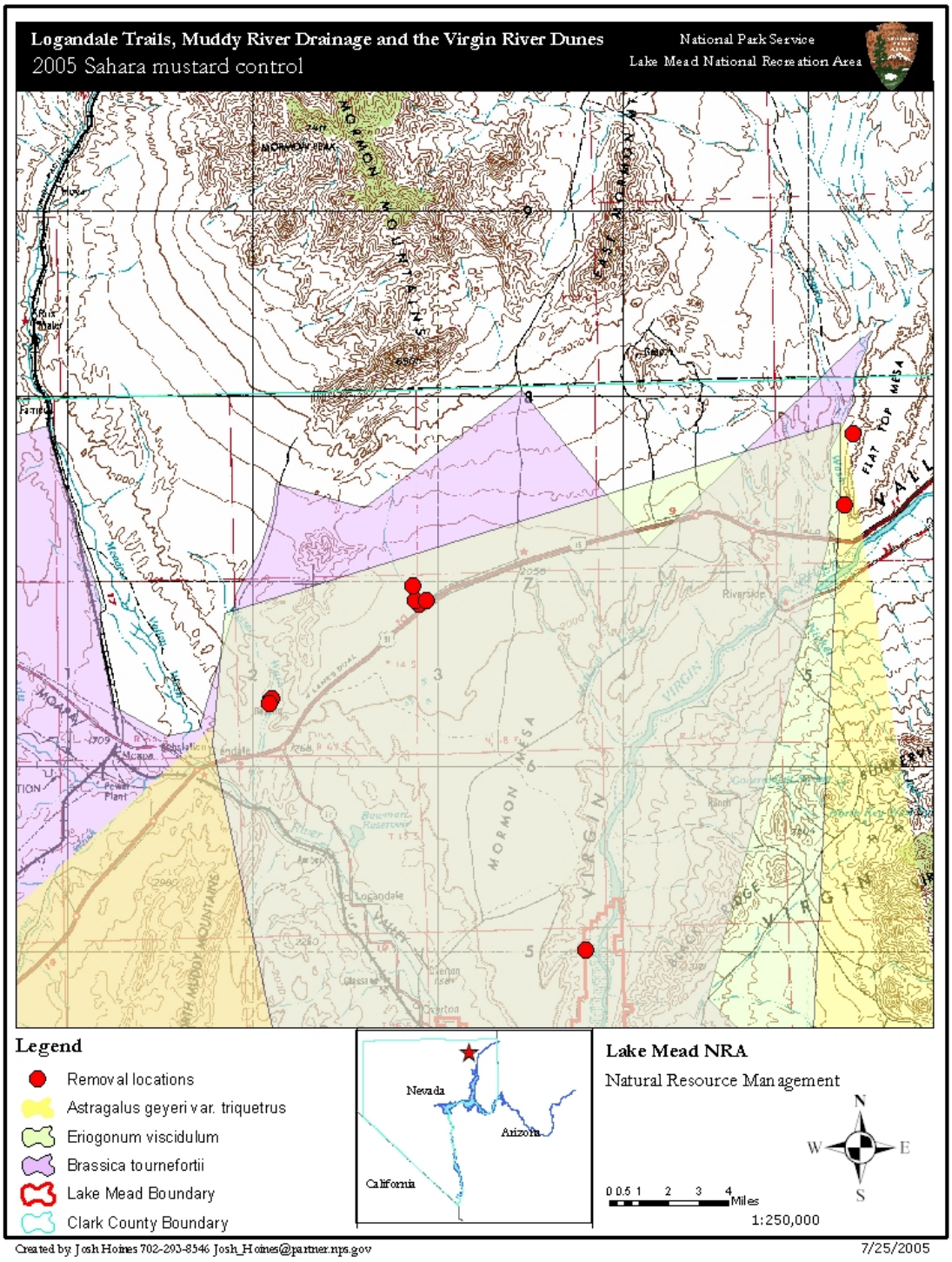
Map 1. *Brassica tournefortii* removal sites at Sandy Cove and other areas within LMNRA during 2004.



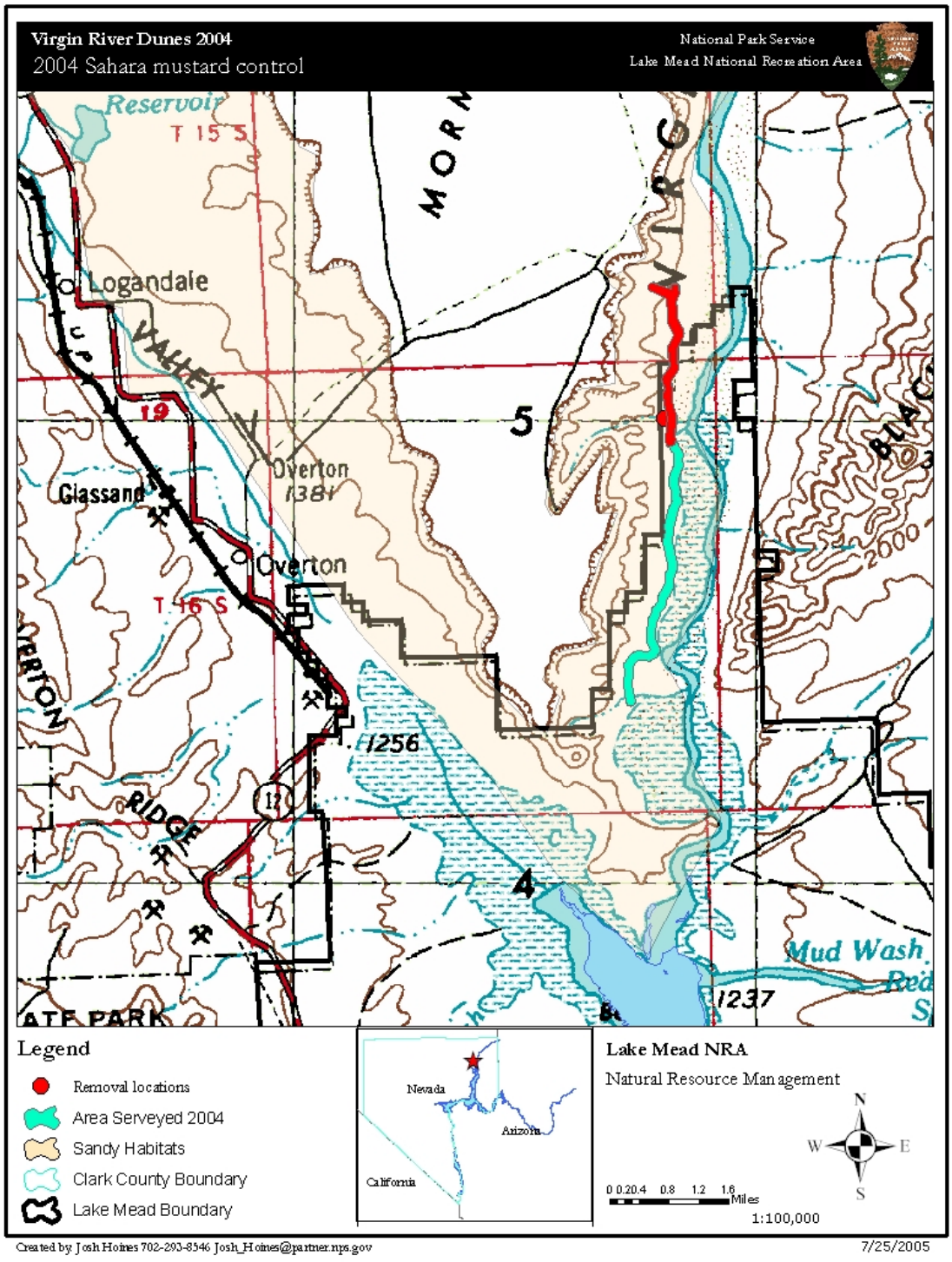
Map 2. *Brassica tournefortii* removal sites at Sandy Cove, LMNRA during 2005.



Map 3. Sites of *Brassica tournefortii* infestations in the Jean Dry Lake area during 200**5.**



Map 4. Sites of *Brassica tournefortii* removal within the Logandale Trails, Muddy River and the Virgin River Dunes (Mormon Mesa area) during 2005.



Map 5. Control sites of *Brassica tournefortii* within Virgin River Dunes areas during 2004

Figure 3. Individual *Brassica tournefortii* plants. Note that in the first photo, even at small sizes, fruiting occurs.

Figure 4. Heavy infestation on sand dune near Cottonwood Cove, NV, in 2003.

Figure 5. Removal efforts for *Brassica tournefortii* at Sandy Cove, 2005.

Figure 6. Sand dunes at Sandy Cove, NV.

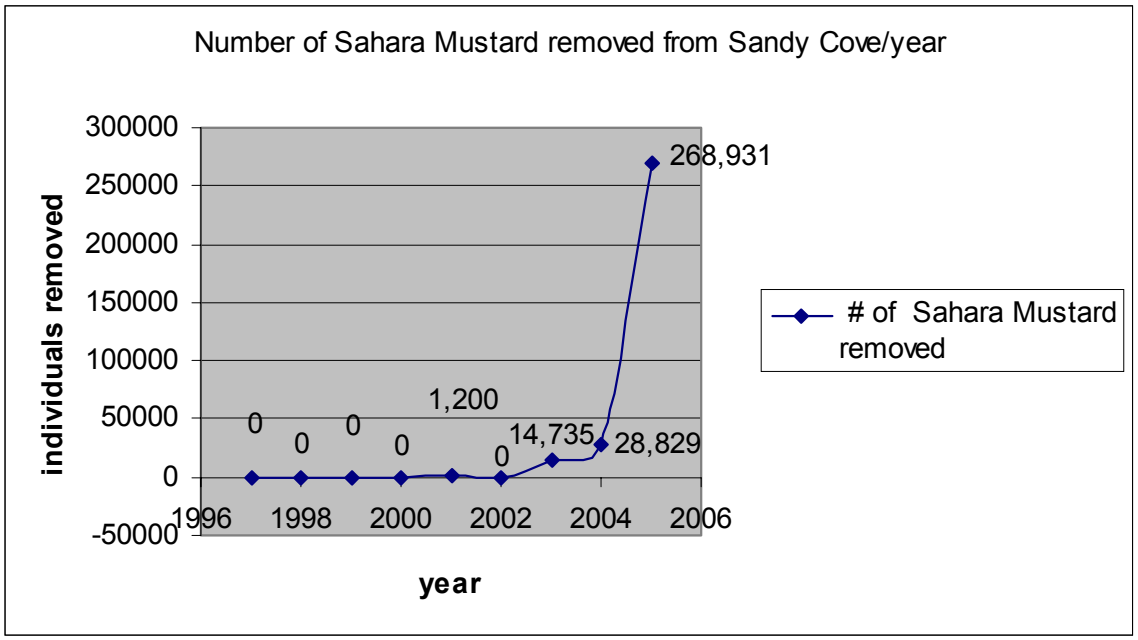


Figure 7. Number of individual *Brassica tournefortii* plants removed or destroyed each year at Sandy Cove (dunes and immediately associated beaches).

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