Implementation of the Conservation Strategy for Tahoe Yellow Cress

(*Rorippa subumbellata*)

V. Experimental Reintroductions, Year Two

prepared for the
Tahoe Yellow Cress Adaptive Management Working Group
c/o Tahoe Regional Planning Agency
158 Market Street
Stateline, NV 89449

by

Bruce M. Pavlik and Alison E. Stanton
BMP Ecosciences
156 South Park, San Francisco, California 94107
bmp333@earthlink.net (415) 543-5115 (510) 430-2158

July 2006

Acknowledgements

We gratefully thank all the members of the AMWG for making this project possible: Leslie Allen, Jan Brisco, Steve Caicco, Eileen Carey, Jody Fraser, Eric Gilles, Shana Gross, Jay Howard, Susan Levitsky, Jennifer Newmark, Peter Maholland, Tamara Sasaki, Roland Shaw, Coleen Shade, Mike Vollmer, and Rita Whitney. We especially thank the USFS, CDPR, and NDSP for providing outplanting sites, fencing, and monitoring and outplanting personnel.

Thank you to the USFS LTBMU for provided funding for the nursery propagation effort and fencing materials.

A warm thanks to all that helped with outplanting: Molly Bernegger (BMP Ecosciences); Beth Brenneman, Jody Fraser, Shana Gross, and Stu Osbrack from the USFS; Jay Howard and Paul Carmichael from NDSP; Roland Shaw from NDF; Shawn Butler, Mark Sedlock, and all the members of the CTC Restoration Crews.

Funding for the project was provided by the Bureau of Reclamation and Nevada Division of State Parks. Thank you to Mike Vollmer, Coleen Shade, and Rita Whitney from TRPA for administering the contract.

We would like to give a special thanks to Shana Gross, Jay Howard, Roland Shaw, and Molly Bernegger for their conscientious monitoring and data entry.

List of Figures

List of Tables

Executive summary

The overall intent of the Conservation Strategy (CS) for Tahoe Yellow Cress (TYC, *Rorippa subumbellata*) is to preclude the need to list the Tahoe yellow cress under the Endangered Species Act (ESA) by restoring its self-sustaining metapopulation dynamic. That dynamic, in which colonization exceeds extirpation, allows the species to persist in sandy beach habitat around Lake Tahoe despite high water levels and human-related impacts (Pavlik et al. 2002a). This is the fourth report in a series (Pavlik *et al.* 2002b, Pavlik and Stanton 2004, and Pavlik and Stanton 2005) that address Conservation Goals 2 and 4 of the CS. Goal 2 calls for improvement of the size and persistence of TYC populations at core and priority restoration sites. Goal 4 requires that research be conducted to directly support management and restoration activities.

The Key Management Question (KMQ) framework that guides conservation and restoration research on TYC is intended to implement the CS by focusing research on decision-making within an adaptive management framework (Pavlik and O'Leary 2002). Since 2003, experimental reintroduction and restoration outplanting trials have included the installation of a total of 6,269 container-grown plants (founders) at 9 sites around the lake. Demographic, physiological, and disturbance monitoring have been conducted at all outplanting sites.

Site selection was based on ecological characteristics, the availability of the agency landowner to install fencing and make in-kind contributions of personnel for outplanting and monitoring, and the patterns of recreational use. Four sites were outplanted during the 2003 pilot project: Avalanche/Eagle Creek in Emerald Bay (CDPR), Taylor Creek at Baldwin Beach (USFS), Zephyr Cove (USFS), and Sand Harbor (NDSP). In 2004, the pilot design was repeated at Taylor Creek and Sand Harbor and two new sites were selected that were large enough to accommodate the installation of replicated plots within a microhabitat: Upper Truckee East (CTC) and Nevada Beach (USFS). The experimental design was repeated at these two sites during 2005. Three additional sites were outplanted in 2005: Ebright Beach at the west end of Baldwin Beach (USFS), Pope Beach (USFS), and Hidden Beach (NDSP). A translocation pilot project, which involved moving established, outplanted individuals from one location to another, was conducted at Taylor Creek in 2005.

Unfortunately, the initial quality and vigor of founding plants was very low in the 2005 cohort, resulting in lower survivorship and reproduction than expected, based on results from similar efforts in previous years. The large effect of poor initial founder vigor swamped the effects of other factors on demographic performance and compromised our ability to draw useful conclusions. Therefore, in this report most KMQs are addressed with data from monitoring the second and third year performance of the 2004 and 2003 cohorts, respectively.

KMQs 1 and 2 address differences in overall habitat suitability among sites and the suitability of microhabitats within a given site, respectively. In all years, survivorship varied among sites and within microhabitats. Survivorship and reproduction were optimal in moist microhabitats and reduced at higher microelevations on all beaches. Overall site suitability, as indicated by demographic performance, tended to support the priority site rankings presented in the CS (e.g., first year performance at Core and High Priority Restoration Sites exceeded that at Low Priority sites).

KMQ 3 addresses those factors that might influence the success of outplanting and, therefore, determines the feasibility of creating or enhancing populations as a restoration tool. Favorable survival and reproduction of two and three year-old plants, regardless of fluctuations in lake level indicated that these created or enhanced subpopulations had high potential for persistence (*sensu* Pavlik et al. 2002a). In addition, three successive years of outplantings at the same sites have yielded markedly different levels of demographic performance, giving support to the concept of spreading the risk of founder investment across years using "founder cost-averaging" to help minimize losses from fluctuating lake elevations or improper nursery care of container-grown plants for the outplanting. Finally, although the pilot investigation of translocation as a potential mitigation measure was compromised by vandalism, the limited data indicate that it is possible to move established plants within a site and that pursuing translocation as a potential mitigation strategy is warranted.

KMQ 4 addresses the importance of using multiple seed lots in restoration efforts. Limited data on population seed source were available from the poor quality founders available in 2005. Consequently, it will be necessary to repeat the experimental reintroduction in another year (e.g. 2006). Robust data from the high quality 2004 founding cohort indicated there was no significant effect of seed source population on survivorship or reproduction. Still, it is not possible to strictly rule out the influence of genetic factors on demographic performance in other years. Until data suggest otherwise it would be appropriate to mix seed from many source populations for restoration purposes to install any unique alleles in founding cohorts.

KMQ 5 focuses on disturbance from visitor use and intense shoreline activity and whether we can mitigate adverse impacts from recreational use. Fencing helped to reduce impacts of recreational activities among the sites, but several enclosures were vandalized during the season or damaged by storm runoff and waves. Improved signage could help reduce vandalism and future efforts will need to more effective method for permanent marking that is less susceptible to vandalism.

Recommendations for 2006:

1) Continue outplanting and repeat the experimental design at a minimum of two sites.
2) Design and implement a translocation study at a minimum of two sites.
3) Ensure the high quality of propagated plants in the greenhouse through close oversight and coordination with nursery personnel.
4) Improve site protection with better signage to prevent or reduce vandalism.
5) Implement public education focused on the role of research and management efforts in the protection of Tahoe yellow cress and Lake Tahoe itself.
6) Pursue other research opportunities in areas that would inform TYC management such as seed bank dynamics, rootstock longevity, and the use of microsatellite DNA analysis techniques.

1.0 INTRODUCTION

The overall intent of the Conservation Strategy (CS) for Tahoe Yellow Cress (TYC, *Rorippa subumbellata*) is to preclude the need to list the Tahoe yellow cress under the Endangered Species Act (ESA) by restoring its self-sustaining metapopulation dynamic. That dynamic, in which colonization exceeds extirpation, allows the species to persist in sandy beach habitat around Lake Tahoe despite high water levels and human-related impacts (Pavlik et al. 2002a). This is the fourth report in a series (Pavlik *et al.* 2002b, Pavlik and Stanton 2004, and Pavlik and Stanton 2005) that address Conservation Goals 2 and 4 of the CS. Goal 2 calls for improvement of the size and persistence of TYC populations at core and priority restoration sites. Goal 4 requires that research be conducted to directly support management and restoration activities.

The Key Management Question (KMQ) framework that guides conservation and restoration research on TYC is intended to implement the CS by focusing research on decision-making within an adaptive management framework (Pavlik and O'Leary 2002). Since 2003, the experimental reintroduction has included the installation of a total of 6,269 container-grown plants (founders) at 9 sites around the lake. The first installation in 2003 was a site-specific, pilot scale project designed to address objectives on techniques for nursery propagation, fencing, outplanting, and monitoring, rather than KMQs. Un-replicated plots were installed in different microhabitats at four sites during the 2003 pilot project: Avalanche/Eagle Creek in Emerald Bay (CDPR), Taylor Creek at Baldwin Beach (USFS), Zephyr Cove (USFS), and Sand Harbor (NDSP). In 2004, the pilot design was repeated at Taylor Creek and Sand Harbor. Two new sites were selected in 2004 that were large enough to accommodate the installation of replicated plots within a microhabitat: Upper Truckee East (CTC) and Nevada Beach (USFS). A replicated design within these sites with "cause and effect" monitoring provided the necessary statistical power to evaluate factors central to the KMQs. In 2005, the experimental design was repeated at these two sites. Three additional sites were outplanted in 2005: Ebright Beach at the west end of Baldwin Beach (USFS), Pope Beach (USFS), and Hidden Beach (NDSP). A translocation pilot project, which involved moving established, outplanted individuals from one location to another, was conducted at Taylor Creek in 2005.

In presenting results from the 2004 experimental reintroduction, the technical report (Pavlik and Stanton 2005) was organized to provide very detailed results from each site and each founding cohort. This year (2005), the format has been streamlined to focus on the effects of the factors that are relevant to TYC management: the effects of initial founder vigor, lake elevation, founder population source, and disturbance. Each of these factors relates to one or more KMQs. For example, ongoing monitoring of the 2003 and 2004 founding cohorts enabled a comparison of the effects of changing lake level on microhabitat characteristics and demographic performance within individual sites (KMQ1). Xylem water potential monitoring (XPP) was measured to make inferences about the effects of plant water status on demographic performance. Such inferences could be used to determine the probability of successful restoration based on differences in hydrology or microclimate between microhabitats within a site (KMQ2). The persistence and reproductive output of two and three year-old founders was used to evaluate success in creating new populations or enhancing existing ones and the ideas of age-structured outplanting and "founder–cost averaging" (KMQ 3). The performance of founders derived from multiple seed sources was evaluated to determine the effects of genotype on survivorship and reproduction in different microhabitats within a site (KMQ 4) and the effects of disturbance were monitored to assess the efficacy of fencing and signage (KMQ5). Taken together, a picture emerges of the requirements of a successful restoration program and we learn about the kind of plants that are required, where, when, and how we can outplant them, and how we can best protect them after installation.

2.0 METHODS

2.1 SEED COLLECTION

Seeds for the 2003 pilot project were collected in September, 2001 at 9 high priority and core restoration sites: Blackwood North and South (combined for planting), Cascade, Edgewood, Lighthouse, Tallac Creek, Taylor Creek, Tahoe Meadows, and Upper Truckee East (Table 1). Seeds for the 2004 pilot project replication and experimental reintroduction were collected in September 2002 at the same sites, except that Regan Al Tahoe was substituted for Edgewood. Seeds for the 2005 experimental reintroduction and restoration plantings were collected in September 2003 at three sites: Edgewood, Taylor Creek, and

Upper Truckee East. Each year, seed lots were cleaned and hand-sorted into two equal lots and stored in manila envelopes at room temperature and humidity. Seeds were delivered to two nurseries in the fall of the collection year. As part of the ongoing propagule production necessary for an age-structured reintroduction, additional seeds were collected in September 2005 for the 2006 efforts.

Table 1. Seed lot of container-grown TYC and year of outplanting in 2003-2005.

Seed Lot/Year Planted	2003	2004	2005
Blackwood	X	X	
Cascade	X	X	
Taylor Creek	X	X	X
Tallac Creek	X	X	
Lighthouse	X	X	
Upper Truckee East	X	X	X
Regan Al Tahoe		X	
Tahoe Meadows	X	X	
Edgewood	X		X

2.2 2005 PLANT PROPAGATION

Two nurseries have conducted the propagation of Tahoe yellow cress for the past three years: The Nevada Division of Forestry (NDF) facility at an elevation of 5,000 ft in Washoe Valley, Nevada; and privately-owned Sierra Valley Farms at an elevation of 5,000 ft in Beckwourth, California. Both followed the same propagation protocol of top sowing-seed in plastic supercells with standard greenhouse soil-less potting mix. A light layer of Lake Tahoe beach sand was sprinkled on the surface to cover the seeds (see Pavlik and Stanton 2003).

Sierra Valley Farm delivered about 1,000 plants to the Washoe Valley nursery three weeks prior to the June planting. These were placed in a lathe house along with 1,000 plants from the Washoe greenhouse. At that time, the plants looked healthy and robust, however they were left un-watered for much of the next three weeks and the plants looked very dry and so were senescent just prior to outplanting. All plants were sorted according to seed lot and then assigned a vigor code (low, medium, or high). The vigor code was a subjective measure of apparent plant health that partially reflected variability from different planting dates, but also the uneven effects of neglect during cultivation.

2.3 SITE SELECTION

Site selection was based on ecological characteristics, the availability of the agency landowner to install fencing and make in-kind contributions of personnel for outplanting and monitoring, and patterns of recreational use.

Un-replicated plots were installed in different microhabitats at four sites during the 2003 pilot project: Avalanche/Eagle Creek in Emerald Bay (CDPR), Taylor Creek at Baldwin Beach (USFS), Zephyr Cove (USFS), and Sand Harbor (NDSP). Descriptions of these "pilot" sites may be found in the 2003 pilot project report (Pavlik and Stanton 2003). In 2004, the pilot project was replicated at two sites: Taylor Creek and Sand Harbor. A new cohort of founders was installed in and among the 2003 plots, effectively doubling the size of the outplanting at each site. Avalanche and Zephyr Cove were not re-planted.

Two new sites were selected in 2004 that were large enough to accommodate the installation of replicated plots within a microhabitat:: Upper Truckee East (CTC) and Nevada Beach (USFS). Descriptions of these sites may be found in Pavlik and Stanton, 2005. Similar site selection criteria as the 2003 pilot project were employed with the additional criteria that the sites needed to be large enough to accommodate a replicated experimental design. The experimental design was repeated at these sites in 2005.

Three additional sites were outplanted during 2005: Ebright Beach and Pope Beach (USFS), both on the south shore, and Hidden Beach (NDSP), located in the northeast corner of the lake. Replicated plots within a microhabitat were not possible in the limited space available at these sites, however, they are part of the experimental program that is designed to answer KMQs and eventually lead to effective restoration prescriptions for establishing or enhancing self-sustaining populations.

2.4 OUTPLANTING DESIGN

In all years, plant installations have consisted of outplanting container-grown founders in "transect" configurations perpendicular to the shore, extending from the waterline into different, upslope microhabitats. (An individual plant is referred to as a "founder" of a new population as part of the reintroduction design.) Transects were placed 3.28 ft (1 m) apart and plants within a single transect were outplanted at 1.6 ft (0.5 m) intervals. Individual founders were marked with wooden stakes. For plots planted with individuals from different seed lots, the stakes were color coded to facilitate planting. Within a plot, a stratified random planting scheme was employed to distribute founders from different source populations as evenly as possible. Low vigor founders were also distributed among the plots as evenly as possible.

2.4.1 TYC MICROHABITATS AND LAKE LEVEL

The microhabitats identified during the 2003 pilot project were refined for the 2004 installation to correlate site microhabitats with elevation and microtopography. The assumption is that the beach water table is at the elevation of Lake Tahoe and, therefore, the microtopographic height of a plot above the lake is equivalent to water table depth. At each site, a laser level was used to determine the precise elevation of each plot in relation to the lake. A total of six microhabitats were described by elevation: moist shoreline, berm, low beach, dune trough, high beach, and meadow (Table 2).

During 2004, moist shoreline habitat occurred from 6,224.6 to 6,225.7 ft LTD in plots adjacent to the lake, generally in rows 1 through 5. This was an arbitrary location, based entirely on the lake elevation on the day of planting that year in May. This elevation band was completely inundated in 2005. However, the first five rows of the plantings at Ebright, Pope, and Hidden Beach were characterized by the same saturated soil conditions and wave inundations that occurred in 2004, so they were designated moist shoreline. At, Nevada Beach, founders were again installed along the banks of Burke Creek to mimic moist shoreline habitat.

Low beach occurred between the moist shoreline and high beach in the range from 6225.8 – 6228 feet. The low beach habitat is susceptible to inundation because maximum lake elevation is approximately 6229 ft. Only the lowest foot of elevation in high beach habitat (6228-6230.6 ft) is susceptible to inundation and this habitat provides a refuge when the lake is full. The berm habitat that formed in 2004 at Upper Truckee East (UTE) was inundated in 2005.

Table 2. Shorezone elevations and plot locations of seven Tahoe yellow cress microhabitats for nine outplanting sites.

Microhabitat	Elevation (ft LTD)	Plot Location
Moist shoreline	6,224.6 to 6,225.7	2003 and 2004 cohorts inundated at all sites but Nevada. In 2005, plots adjacent to the lake at Ebright Beach, Pope Beach, and Hidden Beach in rows 1-5 and at Nevada beach adjacent to Burke Creek.
Berm 1 (May 2004)	6,225.3	Upper Truckee East, blocks 1-5, inundated in 2005
Berm 2 (July 2004)	6,224.7	Upper Truckee East, blocks 1-6, inundated in 2005
Low beach	6,225.8 to 6,227.9	Upper Truckee East, blocks 1-5
		Nevada Beach, blocks 1-3 and rows 6-8 in blocks 4-9
		Avalanche, all
		Ebright Beach, rows 6-14
		Taylor Creek, Plot 2
		Pope Beach Plot 1 rows 6-10
		Zephyr Cove, plot 1 (planted in2003)
		Sand Harbor, rows 15 and less
		Hidden Beach, rows 6-16
Dune trough	6,224.6 to 6,226	Taylor Creek, in back beach plot 3, rows 1-12 and all of plot 4
High beach	6,228 to 6,230.6	Upper Truckee East, blocks 1-5 planted in May, 2004, blocks 1-6 planted in July, 2004, and blocks 1-4 planted in July, 2005
		Nevada Beach, blocks 10-12
		Ebright Beach, rows 15-19
		Taylor Creek, plot 2A and plot 3, rows 13 and above
		Pope, Plot 2
		Zephyr Cove, plot 2 (planted in2003)
		Sand Harbor, plot 1 rows 16-20
Meadow	6230	Taylor Creek, plot 5

Finally, two other microhabitats, including dune trough and meadow, were only present at Taylor Creek. In the back beach, dune trough habitat occurred in the moist sand between 6,224.5 and 6,227.5 ft on either side of a persistent lagoon that supports water lilies (*Nuphar* sp.) and other aquatic vegetation. In 2005, founders from the 2003 and 2004 cohorts were translocated from one of the plots in this habitat (see section 2.7). Beyond the dune trough, plants were installed in the meadow habitat amongst the stabilized vegetation at 6,230 ft.

During 2004 (year 1 of the experimental reintroduction) the first outplanting was conducted in late May with a lake elevation of 6,224.2 ft Lake Tahoe Datum LTD (Figure 1). The highest level of the season, 6,224.3 ft, was recorded 10 days later on June 3rd. The lake dropped to 6,223.9 ft by the second outplanting at Upper Truckee East on July 29th.

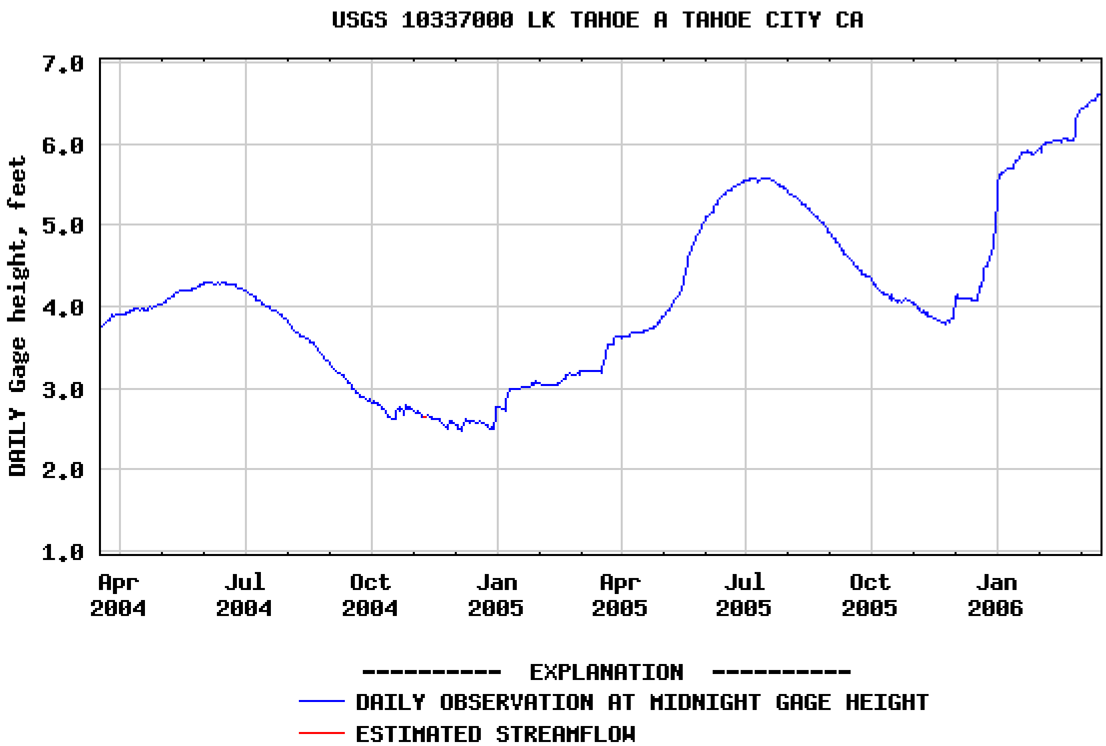


Figure 1. Elevation of Lake Tahoe for the 2004-2005 growing season (add 6,220 ft LTD to gage height on the y axis). Graph from the USGS Tahoe City station.

During 2005 (year 2 of the experiment) the first outplanting was conducted during the week of June 7-10, with a lake elevation of 6,225.1ft LTD. The last day of snowfall for the season was on June 8th and the highest lake level of the season, 6,225.6ft, was recorded later in July. Total survival of the 2005 cohort at UTE at 4 weeks was only 36% and, therefore, all plants were removed, discarded, and replaced with new founders on July 13th. These new plants came from a late propagation at Sierra Valley Farms with 100 additional plants from Washoe nursery that had been sown in March and April.

2.5 2005 FOUNDER INSTALLATIONS AT DIFFERENT SITES

Table 3 presents the number of founders installed at all sites during 2003 to 2005. Site maps for the 2003 cohort pilot sites are in Pavlik and Stanton, 2004; site maps for the 2004 cohort are in Pavlik and Stanton, 2005; and site maps for the 2005 cohort are in Appendix A.

Table 3. The number of founders installed at nine sites at Lake Tahoe from 2003 to 2005.

	# Founders Installed		
Site Name (CS Rank)	**2003 cohort**	**2004 cohort**	**2005 cohort**
Avalanche (Unranked near High)	300		
Zephyr Cove (Medium)	286		
Taylor Creek (Core)	541	546	
Sand Harbor (Low)	297	281	
Upper Truckee East (Core) –June cohort		1,045	650
-July cohort		380	
Nevada Beach (High)		582	534
Ebright (Unranked near High) –June cohort			209
–July cohort			209
Pope Beach (Low)			250
Hidden Beach (Unranked)			180
Total	**1,423**	**2,814**	**2,032**

2.5.1 UPPER TRUCKEE EAST

Upper Truckee East (UTE, owned by the California Tahoe Conservancy) is the expanse of beach on the east side of the mouth of the Upper Truckee River on the south shore of Lake Tahoe. It is designated a “Core Site” in the CS and has the second highest ranking index (78) because the TYC population has been large and persistent over the past 20+ years. Hundreds to thousands plants are typically found scattered over the length of beach, sometimes coalescing into dense mats late in the season. During most years plants have also been counted on the beach west of the river, adjacent to the Tahoe Keys development.

TYC habitat has been protected at the site with a fence running parallel to the shore between the meadow and the high beach. The fence on the east side of the population only extends about 30 feet (10 m) towards the lake from the edge of the meadow. Signs along the lake side that designate habitat are moved as the lake recedes or rises, forming an open "enclosure". Recreational use is light, mostly from nearby residents walking on the beach and occasional sailboarders. Dogs are allowed and there are frequent tracks and scat inside the enclosure.

A complex mosaic of microhabitats is present at UTE. The beach slopes toward the lake with a very gentle gradient so that small fluctuations in lake level can expose or inundate vast expanses of sandy sediment. In 2005, the rise in lake elevation inundated all of the 2004 plots in the moist shoreline and berm microhabitats, as well as thousands of naturally occurring plants. Approximately 15,000 stems had been counted at UTE during the annual survey of September 2004; during the 2005 survey, about 5,000 stems were counted.

Founders at UTE were installed on June 8, 2005 in two microhabitats in blocks of 50 and replicated four times, for a total of 200 plants per microhabitat. The low beach plots were installed adjacent to the 2004 plots and so there was only sufficient space for 4 replicates. The plots were saturated at the beginning of the season when the lake margin was at its highest elevation and lupines became very dense as the growing season progressed. The high beach plots, situated just below the edge of the stabilized dune, were also installed adjacent to the 2004 plots. The high beach microhabitat was very sandy and remained largely free of vegetation cover through-out the season. Additional plots were installed in an "intermediate" microhabitat on the beach between the high and low beach. This microhabitat was also sandy with little natural vegetation.

Four weeks after outplanting only 36% of the new founders had survived. Therefore, the entire June outplanting was removed, discarded and replanted on July 13, 2005. Founders in the new planting were only 3-4 months old and the cohort was not graded for initial vigor because they were all small, vegetative, and fairly uniform in appearance. The cohort was derived only from seed from UTE, so the effects of different source populations could not be tested.

2.5.2 NEVADA BEACH

Nevada Beach (owned by the US Forest Service) is on the east shore of Lake Tahoe, just north of Edgewood golf course. It is designated a "High Priority Restoration Site" in the CS with a ranking index of 47. It was initially classified as a "Core Site", however a stream restoration project constructed near the TYC population inadvertently modified the hydrology of Burke Creek. The adjacent area now supports xeric upland vegetation. One naturally occurring cluster of TYC was present in 2005 in this altered area near the creek. A fence still encloses the upland vegetation and all but the lowest reach of Burke Creek as it drains to the lake.

Fencing could not be extended from the existing enclosure all the way to the shoreline because of recreation and access issues. As installed, the temporary fencing extended 75 feet (22 m) from the old fence, leaving an access corridor of about 25 feet (8 m) between the fence and Lake Tahoe. Although moist shoreline microhabitat along the lake was unavailable, the moist conditions and slight inundations along the edge of Burke Creek were presumably similar to the saturated conditions along the shore of Lake Tahoe and therefore were considered moist shoreline. Both low and high beach microhabitats are present upslope in the coarse sandy beach that is completely free of vegetation cover.

Plants were installed on June 6, 2005 in blocks containing 48 founders each in the moist shoreline and low beach. Blocks of 50 founders were installed in the high beach on the south side of the creek. There were 3-8 replicated blocks for a total of 150-234 founders per microhabitat. All plots were installed directly adjacent to the 2004 plots. One of the 2004 moist shoreline/low beach plots on the steeper south side of Burke Creek (Plot 7) was eroded completely away during the winter, so only 2 new plots were installed on the south side in 2005. Founders derived from seed from UTE, Taylor Creek, and Edgewood source populations were distributed evenly throughout all plots.

2.5.3 Ebright Beach

Ebright Beach, (owned by the US Forest Service) is the far west end of Baldwin Beach on the south shore of Lake Tahoe. It is an unranked site, but is directly adjacent to the "High Priority Restoration Site" on private property called Cascade (ranking index 31). Baldwin Beach is a "Medium Priority Restoration" site. A total of 209 founders were installed on June 9, 2005 in moist shoreline, low and high beach microhabitats in a single plot within temporary fencing. A private fence extends part of the way toward the shoreline to separate USFS land from the private property. Recreational use can be heavy and motorboat mooring is generally concentrated at the west end of the beach.

At the four week monitoring period, only 24% of 2005 founders had survived, so an additional outplanting of 209 was installed among the June planting on July 12, 2005. The surviving 50 individuals from the June planting were not removed to observe if any that appeared dead would re-sprout. All founders were derived from seed from the UTE source population.

2.5.4 Pope Beach

Pope Beach, (owned by the US Forest Service) is on the south shore of Lake Tahoe. It is designated a "Low Priority Restoration Site" in the CS with a ranking index of -37. Founders were installed on June 7, 2005. The installation was divided into two plots and enclosed in temporary fencing. The lower plot contained 60 individuals in the moist shoreline adjacent to the lake 60 founders in the low beach microhabitat. The upper plot contained 130 founders in high beach microhabitat. All founders were derived from seed from the UTE source population. Recreational use is heavy and the plots were situated towards the east end of the beach.

2.5.5 Hidden Beach

Hidden Beach, (owned by the Nevada Division of State Parks), is located in the northeast corner of the lake and is accessed by boat or a sloping foot trail from Highway 28 that begins directly across from the Flume Trailhead. This clothing-optional beach stretches along a small cove that receives heavy recreational use, despite the obscure location. It is an unranked site that has been surveyed for Tahoe yellow cress since 2002. In 2005, a cluster of 7 naturally occurring plants were growing among some boulders at the north end of the beach. The outplanting plot was installed on June 10, 2005 at the south end of the beach and enclosed with wood post and wire fencing. A total of 180 founders were installed in moist shoreline and low beach microhabitats. All founders were derived from UTE seeds.

2.6 Monitoring

2.6.1 Demographic

Demographic monitoring techniques developed for the 2003 pilot project were employed in the present study. Detailed protocols are available in Pavlik and Stanton (2003). A datasheet was developed to record the fate of every outplanted founder, allowing subsequent calculations of mortality rates, survivorship to reproduction, and estimates of reproductive output using models previously developed (Pavlik *et al*. 2002b). Three of the land management agencies (USFS, CTC, and NDSP) committed personnel for outplanting and ongoing monitoring efforts throughout the 2005 growing season. Founders were evaluated at two weeks and four weeks after planting and thereafter on a monthly basis through September. Data collection parameters included: plant position, seed source, phenology, vigor, initial and final plant size, and current status. Reproductive output was estimated based on an equation that links canopy size to seed output ($y=3.609x-109.542$, $r^2 = 0.81$) (see Figure 4 in Pavlik *et al.* 2002b).

2.6.2 Physiological

The water relations monitoring component measured physiological stress levels (i.e., xylem water potentials) of plants established at different hydrotopographic positions with respect to lake level. Monitoring of plant water status was conducted three times during the 2005 growing season; July, August, and again in late September during the period of maximum reproduction. An attempt was made to cluster monitoring days and obtain the measurements under seasonally “typical” conditions: clear, sunny, warm, and not within 5 days after a storm front had passed. Xylem water potentials were measured with a pressure bomb at two times during the day: predawn (5-6 am, before direct sunlight), and midday (2-4 pm), the period with warmest air temperatures and lowest humidity. TYC stems were excised with a razor blade and immediately inserted into the pressure bomb for measurement. Within a microhabitat, individuals were selected based on position, apparent vigor, and sufficient size so that one stem could be excised without significant harm to the plant. Only individuals from the 2004 cohort were sampled, as most individuals in the 2005 cohort were too small or of poor quality.

July measurements were conducted on July 11-14 at four sites (UTE, Nevada Beach, Taylor Creek, and Sand Harbor). Pre-dawn temperature was 48-50° F and midday was 82-85 ° F at three of the sites (Sand Harbor data was eliminated due to unusually high pre-dawn temperatures). August measurements at UTE and Nevada Beach were conducted on August 8-9, with pre-dawn temperatures of 48 and 50° F and midday of 80 and 76° F, respectively. September data was collected at UTE and Nevada Beach on September 14-15 with pre-dawn temperatures of 39° F and midday of 69 and 70° F. Air temperatures during the 2004 measurements were comparable in July (pre-dawn, 48-52° F ; midday, 80-82 ° F) but slightly warmer in September (pre-dawn, 39-40° F ; midday, 72-76 ° F).

2.6.3 Disturbance

Disturbance monitoring was conducted in conjunction with the demographic monitoring. Additional disturbance monitoring was conducted on July 5th in an attempt to document any impacts from high recreational use the 4th of July weekend. During the demographic monitoring, the crews made notes about the following possible disturbances in the plots: footprints/body impressions, animal prints (especially dogs and Canada geese), trash, and any acts of vandalism, especially those affecting Tahoe yellow cress plants or the fence/signs. Photographs were taken of any significant disturbances.

2.7 Translocation Pilot Project

Translocation involves moving established plants in the field from one location at a site to another. A total of 56 founders from the 2003 and 2004 cohorts in dune trough habitat (Plot 3) at Taylor Creek were carefully dug up and moved within the existing enclosure on June 24, 2005. Each individual was extracted using a sharp shooter shovel and placed in a pot with a variable amount of soil still attached to the roots. Care was taken to cut around the perceived rootmass to minimize damage, but it was not always possible to get all roots due to extensive rooting depth and width.

Translocation plots were established in 4 replicated blocks around the perimeter of the back beach dune trough within 300 ft (100m) of Plot 3 to the east. Each replicated block consisted of two treatments: amended with soil-less potting mix, and no potting mix. Each block contained 7 individuals for a total of 28 individuals per treatment. Each planting area was pre-watered to allow digging of a hole approximately one foot deep in order to accommodate the rootmass without bending. For the amendment treatment, approximately 1 gallon of potting mix was mixed in the hole with the sandy substrate before planting. Each plant was carefully planted and secured in the ground before more water was applied. The seven individuals in a block were laid out in a clumped design and each plant marked with a wire flag. Plots were monitored at two, four, and eight weeks after planting.

3.0 RESULTS

This section of the report is organized by the factors that influence demographic performance including the effects of founder initial vigor, lake level, microhabitat, founder water status, and founder seed source. These factors are central to an evaluation of the Key Management Questions (KMQs) (Pavlik and O'Leary 2002). For instance, continued monitoring of the 2003 and 2004 cohorts enabled a comparison of the effects of changing lake level on demographic performance of TYC and persistence through time. The persistence and reproductive output of two and three year-old founders can then be used to evaluate success in creating new populations or enhancing existing ones (KMQ 3). Physiological monitoring of xylem water potentials was used to make inferences about the relationship of founder survivorship or reproduction with plant water status in different microhabitats (KMQ 2) and response to changing lake elevation. Correlation between demographic performance and water status among sites enabled predictions about the probability of successful restoration at a site based on microhabitat characteristics related to hydrology or microclimate (KMQ 1).

First and second year results from UTE and Nevada Beach are presented with any supporting statistical analysis for the replicated plots within a microhabitat. First year results from Pope

Beach, Ebright Beach, and Hidden Beach are presented, however, statistical evaluation at these sites was limited to measurements on individual plants for reproductive output since the plots were not replicated within microhabitats. Second and third year results from the 2003 pilot outplanting sites (Avalanche, Taylor Creek, Zephyr Cove, and Sand Harbor) are presented when relevant.

3. 1 Effects of Initial Founder Vigor

One conclusion from the 2003 pilot project was that founders with high initial vigor were two to three times more likely to survive than those with low initial vigor. In 2005, 71% of all founders were classified with low initial vigor (including all of the July re-planting at UTE and the second planting at Ebright). In comparison, 48% of the cohort at the 2004 sites was classified as low vigor and only 14% of the 2003 cohort had low initial vigor. Overall survivorship in 2005 ranged from 5-46% among the sites and rates of reproduction ranged from 0 at Hidden Beach to only 34% at Ebright (Figure 2). Both survivorship and reproduction were much lower than expected based on previous years. First year survivorship ranged from 43-77% in 2004 and from 27-86% in 2003. First year reproduction was also much higher in 2003 and 2004.

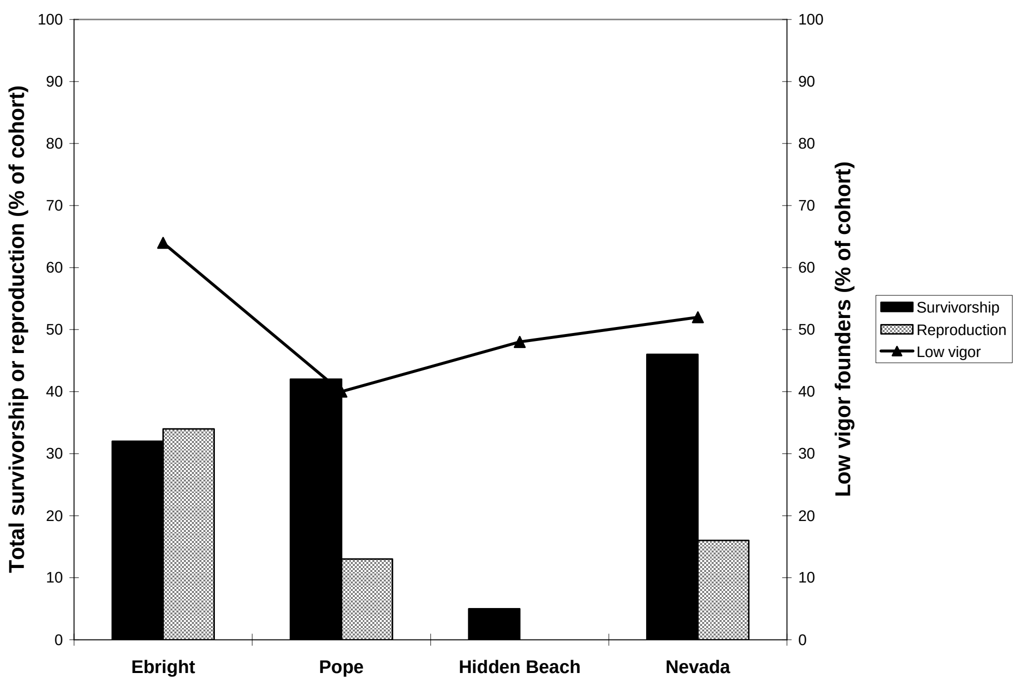


Figure 2. The effect of initial vigor on survivorship and reproduction in the 2005 cohort at four sites in September, 2005. The cohort at UTE was not evaluated for initial vigor so it is not included here.

At UTE, the poor quality of 2005 founders severely compromised the experimental outplanting. After four weeks, only 36% of the total had survived. In contrast, mean survivorship in 2004 at four weeks ranged from 75-95% among all microhabitats. Therefore, the entire June planting was removed, discarded and re-planted. The new founders were only 3-4 months old, fairly uniform in appearance, small and vegetative. Therefore, the cohort was not graded for initial vigor and it was not possible to analyze the effects of plant quality on demographic performance. Likewise, the cohort was derived from only one seed source population, so the effects of genetics could not be tested in this second year.

Initial founder vigor also compromised the experiment at Nevada Beach where a majority (52%) of the founders was classified as low vigor. Although survivorship after four weeks was only 54% (compared to almost 90% at the same time in 2004), the site was not re-planted. Overall survivorship at the end of the season in September was only 46%, far less than the 75% observed during 2004. The reduced survivorship could possibly be a result of the rise in lake elevation, but more likely it was due to the low quality of the plants.

Among Ebright Beach, Hidden and Pope Beach, initial founder plant vigor was also very low. At Ebright Beach, only 24% of the outplanting was surviving after four weeks, so an additional outplanting of 209 founders was installed in July. However, the original 50, low vigor individuals were not removed to observe if any that appeared dead would re-sprout. By September, some of the June cohort did re-sprout and survivorship rose to 32%. Survivorship of the July cohort was only marginally better at 42%, and reproductive proportions were low (34% and 10% in the June and July cohorts, respectively). Figure 2 and subsequent analysis is based upon combined data for the two plantings at Ebright Beach. The June planting at Pope Beach also had low survivorship (42%) and negligible reproduction (10%). At Hidden Beach, only 9 individuals (5%) of the original planting of 180 founders survived to September, precluding any further analysis at this site.

While the overall poor performance of the 2005 cohort was apparently due to the low initial vigor of the founders, a statistical analysis of the interaction between survivorship and vigor was only possible at Nevada Beach. Unexpectedly, there were no significant differences in mean survivorship of low, medium, or high vigor plants among the plots or between plots on different creek aspects. While it is possible that the rise in lake elevation could have been responsible for the poor performance, physiological monitoring indicated that the water status of plants improved in 2005 when compared to 2004 (see section 3.4). More likely, the lack of significant effects of founder vigor on survivorship or reproduction stemmed from the fact that our method of evaluating founders did not accurately categorize vigor or TYC's resilience. Initial vigor is a relative measure based on shoot appearance. The overwhelmingly poor appearance of the majority of 2005 founders likely led the observers to categorize some as high vigor (e.g. those with a few green leaves) even though all had been severely stressed during the final days of propagation. In reality, there were no high vigor founders among the 2005 cohort (as assessed in previous years) and this compromised the experiment.

3.2 Effects of Lake elevation

Lake elevation reached a high of 6225.6 feet (LTD) on July 1, 2005. The previous year, the high lake elevation of 6224.3 feet occurred at the beginning of June (see Figure 1). The increase in lake elevation of over one foot would have several expected outcomes: 1) inundation of the moist shoreline microhabitat, defined in 2004 as occurring between 6,224.6 to 6,225.7 feet, 2) improved water status of founders in remaining microhabitats (as measured by xylem water potentials), and 3) increased performance of founders in more xeric habitats (high beach) due to increased water availability.

Higher lake levels during 2005 inundated the moist shoreline, eliminating nearly all of the 2003 and 2004 founders from the microhabitat. What had been an optimal in 2004, with survivorship at most sites exceeding 80%, became uninhabitable in 2005 with zero survivorship or reproduction. It is not known if the 2003 and 2004 founders will persist underwater and reappear (*sensu* the CS) when the water eventually recedes.

Although many founders were under water and/or buried under sand in the lowest elevation microhabitats, higher lake levels did improve the water status of founders in the remaining, upslope microhabitats. Xylem water potentials of the 2004 cohort measured in 2005 were significantly higher across all microhabitats than in 2004 (see section 3.4). This probably means there was greater water availability and that plants were experiencing less stress (xylem tension) during 2005, given that atmospheric conditions were similar. Improved water status was accompanied by significant increases in mean seed output per plant in all microhabitats during 2005 (Figure 3), although founders were also a year older and correspondingly larger in size. Increased water availability and longer establishment period may have allowed two year-old founders to expend more energy on both vegetative growth and seed production.

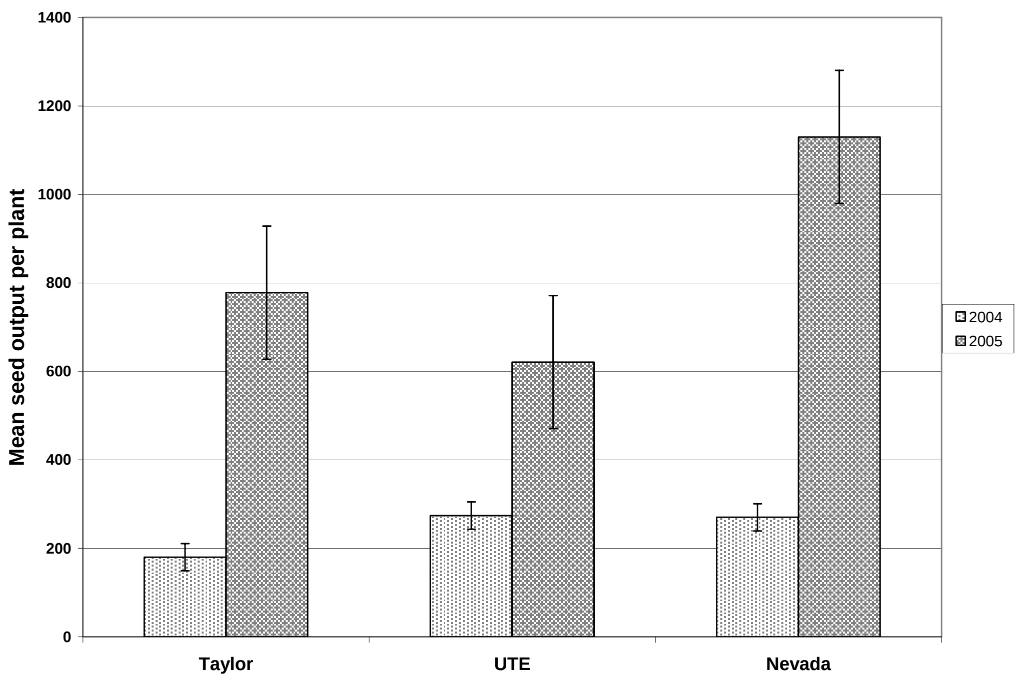


Figure 3. A comparison of mean seed output per plant in the 2004 cohort at three sites in September of 2004 and 2005. Bars indicate ± 1 SD. (Sand Harbor was not evaluated for reproductive output in 2005).

Increased water availability was expected to improve performance of plants in the high beach during 2005 compared to 2004. However, survivorship and reproduction in the high beach among the 2005 cohort at UTE and Nevada were not significantly different when compared to the 2004 cohort (see section 3.3). Likewise, survivorship in the high beach at Ebright Beach, Hidden and Pope Beach was low and reproduction failed completely. We attribute this outcome to the low initial vigor of the founders. Such a large proportion of the 2005 founders died so soon after planting that the low quality of the plants overwhelmed any potential benefits from greater water availability.

3.3 Performance in Different microhabitats

Differences in founder performance in the three microhabitats varied among sites in the 2005 cohort (Figure 4). The greatest founder survivorship was in the low beach habitat at UTE. Survivorship was fairly high in the moist shoreline habitat at Nevada Beach and Ebright but low at Pope Beach, where the first three rows were inundated. Founders at Pope Beach had the best performance in the high beach. Hidden Beach was inundated by storm waves in July and only 5 founders survived until September. As previously mentioned, the inconsistency and lack of a clear pattern in demographic performance among the sites was likely due to the overall low initial quality of the founders.

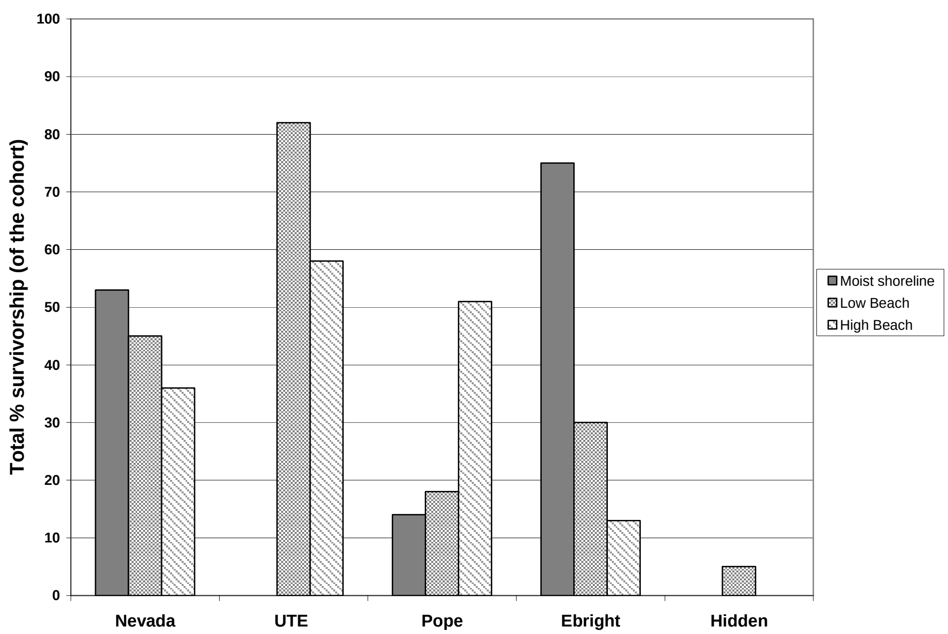


Figure 4. Total survivorship in three microhabitats of the 2005 cohort in September, 2005 (the moist shoreline was not available for planting at UTE)**.**

At Nevada and UTE mean survivorship to reproduction was significantly reduced in the high beach at both sites compared to the more mesic microhabitats(Tables 4 and 5). At Nevada Beach there was no significant difference between founder performance in the low beach or moist shoreline, although total seed production was higher in the moist shoreline (Table 4). At UTE, mean survivorship to reproduction was significantly greater in the low beach than the intermediate microhabitat and although plants were larger, this did not translate to significant differences in mean seed output per plant (Table 5).

Table 4. Mean survivorship and reproductive output of the 2005 cohort in three microhabitats at Nevada Beach in September, 2005. Mean values in a column followed by different letters are significantly different (ANOVA p<0.02).

Microhabitat	Mean Survivorship to Reproduction (%)	Mean Canopy Area (cm2)	Mean Seed Output (#/founder)	Total Seed Production (# /microhabitat)	Total Plantlet Production (#/microhabitat)
Moist shoreline	5a	94a	246a	8,104	7
Low beach	2a	57a	173a	2,250	1
High beach	0b	na	0	0	0

Table 5. Mean survivorship and reproductive output of the 2005 cohort in three microhabitats at Upper Truckee East in September, 2005. Mean values in a column followed by different letters are significantly different (ANOVA p<0.02).

Microhabitat	Mean Survivorship to Reproduction (%)	Mean Canopy Area (cm2)	Mean Seed Output (#/founder)	Total Seed Production (# /microhabitat)	Total Plantlet Production (#/microhabitat)
Low beach	55a	104a	400a	41,235	0
Intermediate	16b	32b	243a	7,051	0
High beach	<1c	5c	0	0	0

Data from the 2003 pilot and the 2004 experimental outplanting demonstrated that, in general, survivorship was maximal in the mesic microhabitats (moist shoreline, berm, and low beach) and significantly reduced in the more xeric high beach insert reference to graphs in 04 report. During 2005, mean seed output of two-year olds was maximal in the low beach at Nevada Beach, UTE, and Taylor Creek (seed output was not estimated at Sand Harbor)

(Figure 5). Reproduction in the moist shoreline only occurred along Burke Creek at Nevada Beach, but mean seed output in that habitat was not significantly different from the high beach. Second year mean seed output was lowest in the high beach. However, mean seed output in the high beach increased significantly from 2004 to 2005 (Figure 6), likely due to improved water status (see section 3.4).

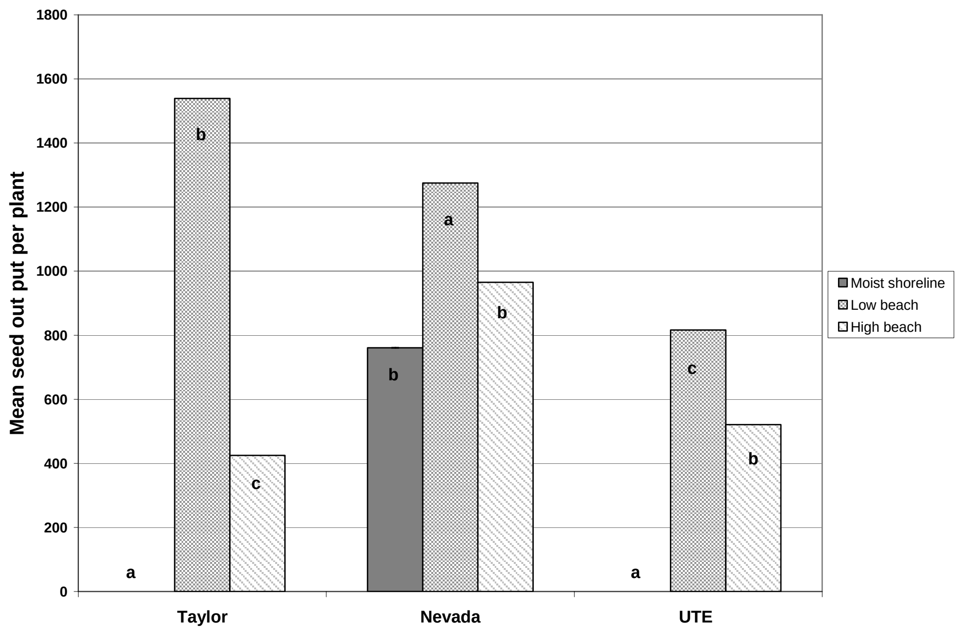


Figure 5. Mean seed output per plant of two year-old founders in three microhabitats at three sites in September 2005. Mean values with different letters for each site are significantly different (ANOVA $p<.01$).

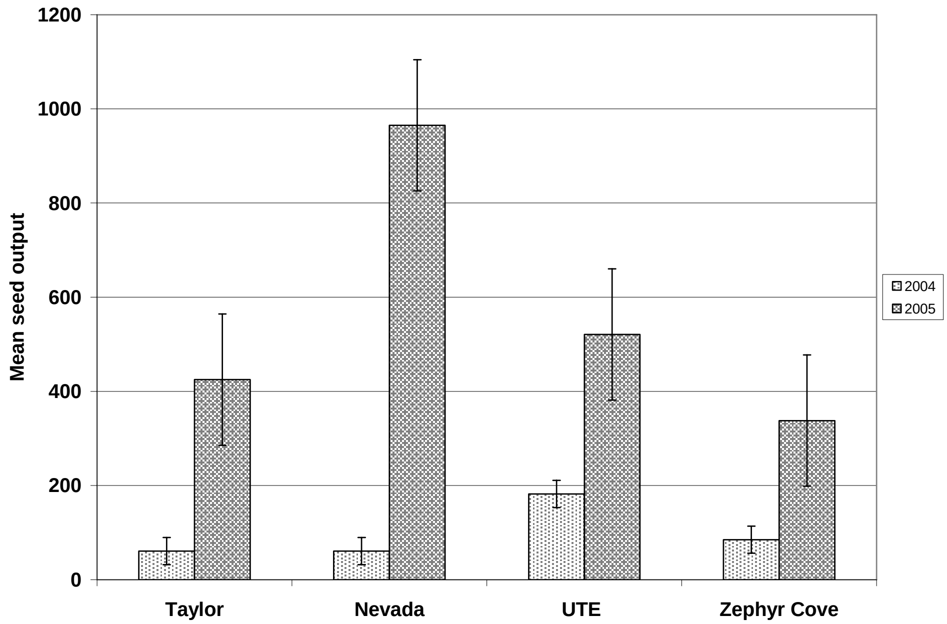


Figure 6. Mean seed output per plant of two and three year-old founders in the high beach at four sites in September 2004 and 2005. Bars indicate + 1 SD.

The patterns of survivorship and reproduction in the 2004 cohort at Nevada Beach shifted among microhabitats during 2005. Reproduction of one year olds was optimal in the moist shoreline in 2004, but optimal in the high beach in 2005 (Figure 7). Among one year-old founders in 2005, reproduction was still maximal in the moist shoreline as it had been in 2004, however, reproduction did not occur at all in the high beach. As previously mentioned, the increase in lake elevation was expected to increase founder performance in previously xeric habitats. The lack of first year reproduction in the high beach was likely due to the low initial vigor of the entire cohort, especially given that two year old founders experienced a large increase in reproductive capacity and output in the high beach in 2005. This pattern was also evident at UTE, with no reproduction in the high beach among the 2005 cohort and increased reproduction in both the low and high beach among two year-old founders. These observed increases in reproductive output in two year-old founders in 2005 are likely attributable to a combination of improved water status and improved growth after a second season.

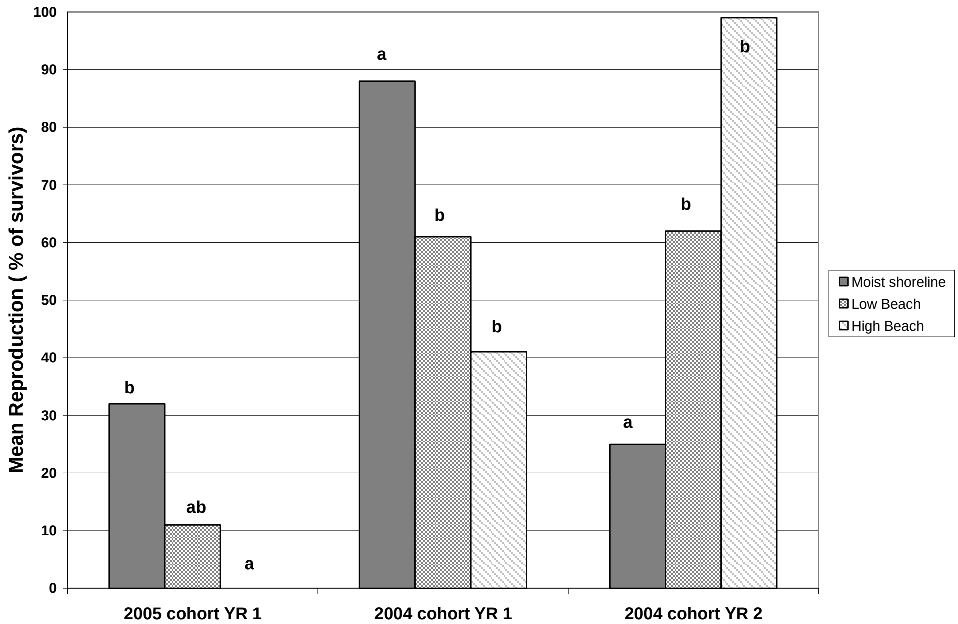


Figure 7. Mean reproduction (the proportion of survivors) of one year-old and two year-old founders at Nevada Beach, September 2005. Mean values with different letters for each site are significantly different (ANOVA $p<.01$).

3.4 PLANT WATER STATUS

The xylem water potential (Ψx) of vascular plants integrates soil water availability and atmospheric moisture conditions in a single, plant-based measurement of water status (using a pressure bomb). Well-hydrated plants have higher water potentials [less negative and closer to 0 bars or 0 MPa (megapascals)] because water is moving through the plant under low tension (negative hydrostatic pressure). As water becomes less available in the soil to replace transpiration losses to the atmosphere, xylem water potentials decrease (i.e., become more negative) and the plant experiences greater stress (e.g., possible loss of cellular turgor pressure and other physiological perturbations). Xylem water potentials of forbs in mesic habitats generally ranges from at or near 0 bars for a fully hydrated plant to a lower threshold of –15.0 bars (-1.5 MPa) for a stressed plant that is at or near the point of wilting.

Pre-dawn water potentials taken before the sun appears in the sky (generally before 6am), provide an indication of available soil moisture because stomata have been closed overnight and the water potential of the plants has equilibrated with the water potential of the soil. For the data pooled across all sites and microhabitats, pre-dawn water potentials (the least stressful in a 24 hr cycle) were significantly higher in 2005 than 2004 from July to September For the data pooled across all sites and microhabitats, pre-dawn water potentials (the least stressful in a 24 hr cycle) were significantly higher in 2005 than 2004 during July and September (Figure 8), indicating that 2005 founders experienced significantly less water stress than those in 2004. This also held true in separate microhabitats (data not shown), and air temperature were comparable between the years (around 50°F in July and 40°F in September), indicating that founders in 2005 experienced significantly less baseline water stress than those in 2004.

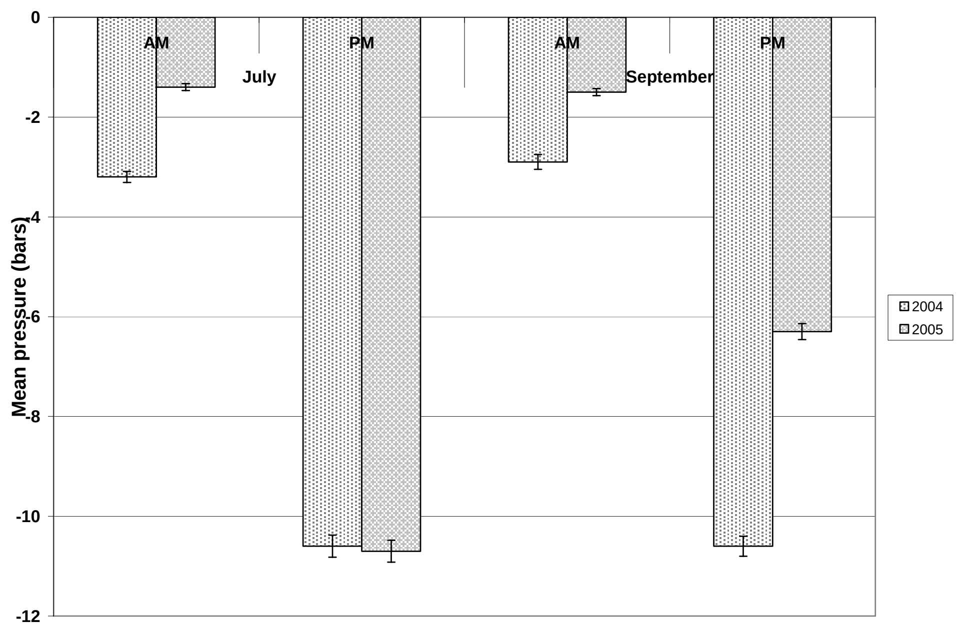


Figure 8. Mean water potentials at pre-dawn (AM) and midday (PM) of Tahoe yellow cress in July and September of 2004-2005. Data pooled from all sites. Bars indicate ± 1 SE.

It is likely that the increase in lake elevation was responsible for the improved water status of founders in 2005. Mid-day water potentials (when plants are most likely to experience water stress) were significantly different between the years only in September, when plants were experiencing greater water stress due to lower soil moisture associated with a lower water table. Some of the observed differences in late season water potential could be attributable to differences in the ambient conditions when measurements were made, (air temperatures in September were between 72-76° F in 2004 and 69-70°F in 2005.)

Mean midday water potentials in the high beach were significantly lower at Nevada compared to UTE in July and September (Figure 9), indicating that plants were experiencing higher water stress at the former. There was no significant difference among pre-dawn water potentials at the sites, indicating that the increased stress in the afternoon was due to atmospheric factors, such as air temperature, wind, or relative humidity that may have had a greater effect than differences related to soil moisture. Nevada Beach, on the eastern shore of the lake, has consistently higher air temperatures that would increase evapotranspiration and decrease xylem water potentials at midday. The reversal of the midday pattern during August, where plants were more stressed at UTE than Nevada Beach, may have similarly been a factor of differences of atmospheric factors, rather than soil moisture.

For data pooled across all sites, founder water potentials were significantly different among the microhabitats during July (Figure 10). Founders were less stressed in the moist shoreline microhabitat and experienced the highest stress levels in the high beach. This difference disappeared later in the season, perhaps as the result of root system growth after outplanting, or as atmospheric factors outweighed differences related to soil moisture.

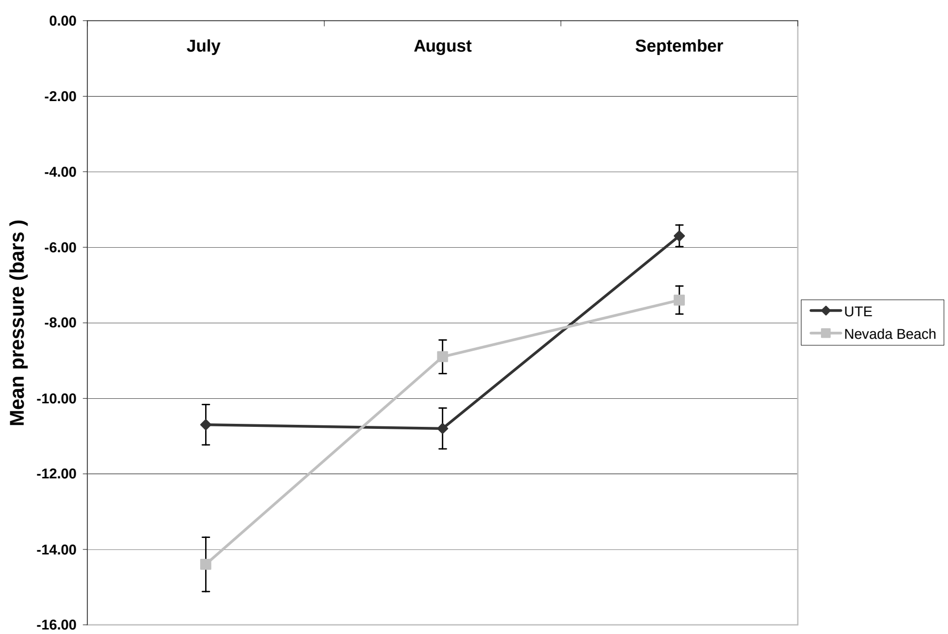


Figure 9. Mean midday water potentials of Tahoe yellow cress in the high beach at Upper Truckee East and Nevada Beach during the 2005 growing season. Bars indicate ± 1 SE.

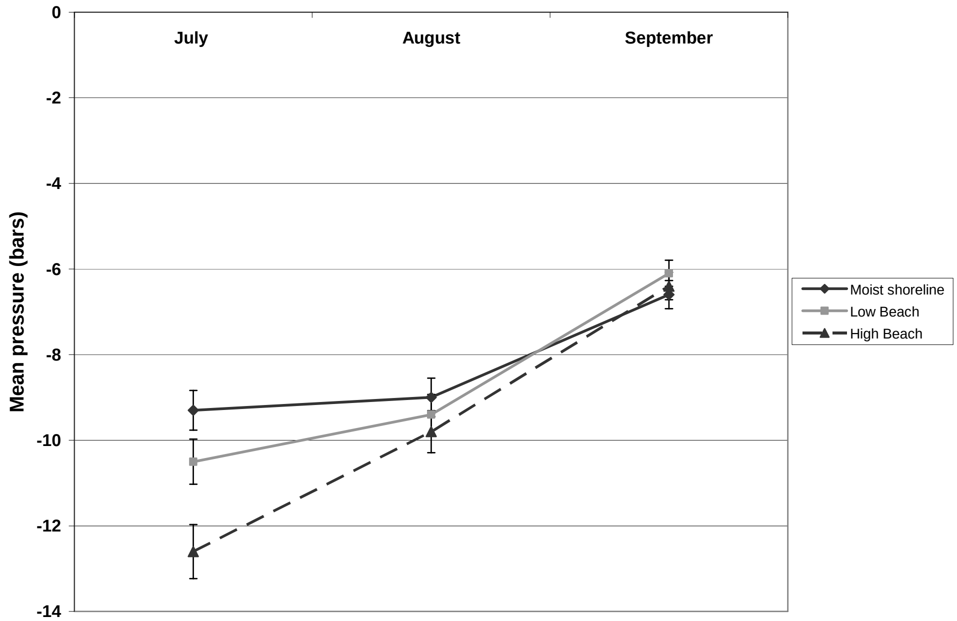


Figure 10. Mean midday (PM) water potentials of Tahoe yellow cress in three microhabitats during the 2005 growing season. Data pooled from all sites. Bars indicate ± 1 SE.

3.5 EFFECTS OF FOUNDER SEED SOURCE POPULATION

In 2005, it was only possible to evaluate the effects of founder source population on survivorship and reproduction at Nevada Beach (July founders replanted at UTE in were from a single population). At Nevada Beach, founders from UTE seed had significantly greater survivorship in September than those from Taylor Creek or Edgewood, but the proportion of survivors that went on to reproduce were similar among the seed sources (Figure 11).

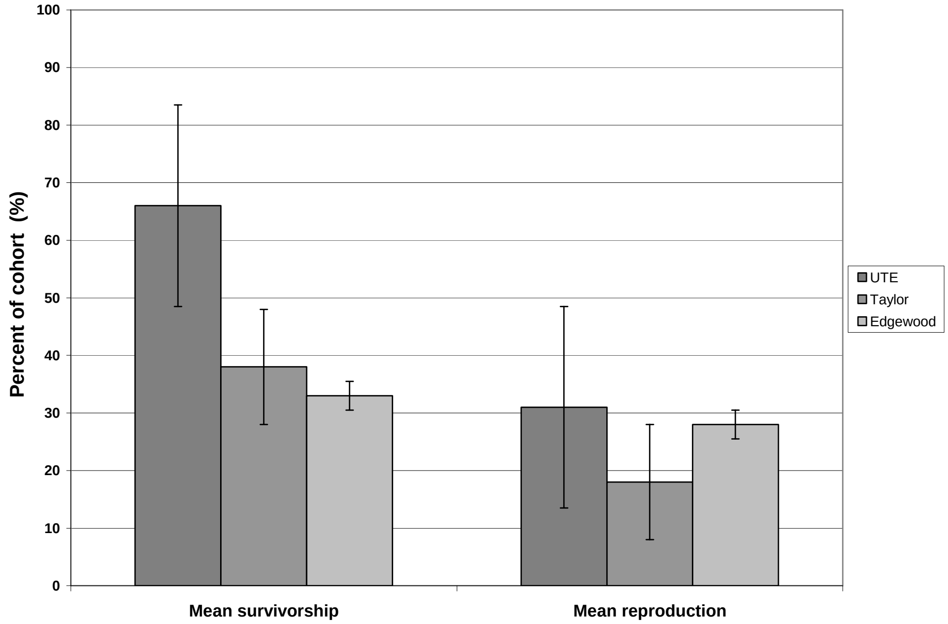


Figure 11. Mean survivorship and reproduction of three population sources at Nevada Beach, September, 2005. Bars indicate ± 1 SD.

However, founders from UTE were four times more likely to be high vigor and significantly less likely to be low vigor. Only 29% of founders from UTE were low vigor compared to 76% from Edgewood, and the superior performance of UTE founders is likely due to this discrepancy. Still, it is not possible to strictly rule out the influence of environmental or genetic factors because of the overall low survivorship and compromised nature of the experiment. The criteria for evaluating initial vigor also varied and undermined the assessment of performance differences, as discussed in section 3.1. Population source was not found to have a significant effect on survivorship or reproduction in 2004 when the quality of the cohort and the data were robust, but it will be necessary to repeat the 2005 experimental design to verify these findings. Until data suggest otherwise it would be appropriate to mix seed from many source populations for restoration purposes to install any unique alleles in founding cohorts (see DeWoody and Hipkins 2004)

3.6 PERSISTENCE THROUGH TIME

Total survivorship for the 2003 founding cohort has steadily declined over the past two years (Figure 12). First year survivorship in 2003 ranged from 86% at Avalanche to 27% at Sand

Harbor. Some of the initial losses at Sand Harbor were due to inundation of and wave impacts to moist shoreline founders (all of original Plot 3 was gone by the end of the first season). Second year survivorship was maximal at Avalanche Beach, moderate at Zephyr Cove and Tayor Creek, and low at Sand Harbor. During 2005, inundation reduced survivorship to approximately 45% at Avalanche and Zephyr Cove, and only 20% at Taylor Creek and Sand Harbor. Inundation was greatest at Taylor after Taylor Creek had eroded away the entire moist shoreline plot and inundated most of the low beach. By the end of the 2005 field season, there were 386 founders, or 27% of the 2003 cohort alive at all sites (not including the 58 plants that were translocated at Taylor), down from 750 in 2004. Of these survivors, 309 (80%) were fruiting in September 2005. Of the initial investment of 1,424 founders, almost 22% survived to reproduce three years later. Over this entire period, survivors produced an estimated 500,000 seeds as offspring (not including the missing estimates from Sand Harbor for 2003 and 2005).

The ongoing rise in lake level caused sharper declines in the size of the 2004 cohort. Total first year survivorship was approximately 75% at each site except Sand Harbor (43%). In 2005, the average decline in survivorship among the sites was close to 60%. While 47% of the founders survived at Nevada, less than 25% of founders persisted at the other three sites (Figure 13). The higher persistence at Nevada is attributable to less inundation. Only 24% of the 2004 cohort at Nevada Beach was inundated in 2005, compared to 50% at UTE, 54% at Taylor Creek, and 42% at Sand Harbor. Of the initial investment of 2,814 founders, a total of 636 (23%) were surviving at the end of year two. Of these, a total of 496 were reproductive in September, for an overall survivorship to reproduction of 18%, only slightly lower than third year reproduction in the 2003 cohort. Over the two year period, survivors produced an estimated 700,000 seeds as offspring (not including the missing estimates from Sand Harbor for 2003 and 2005).

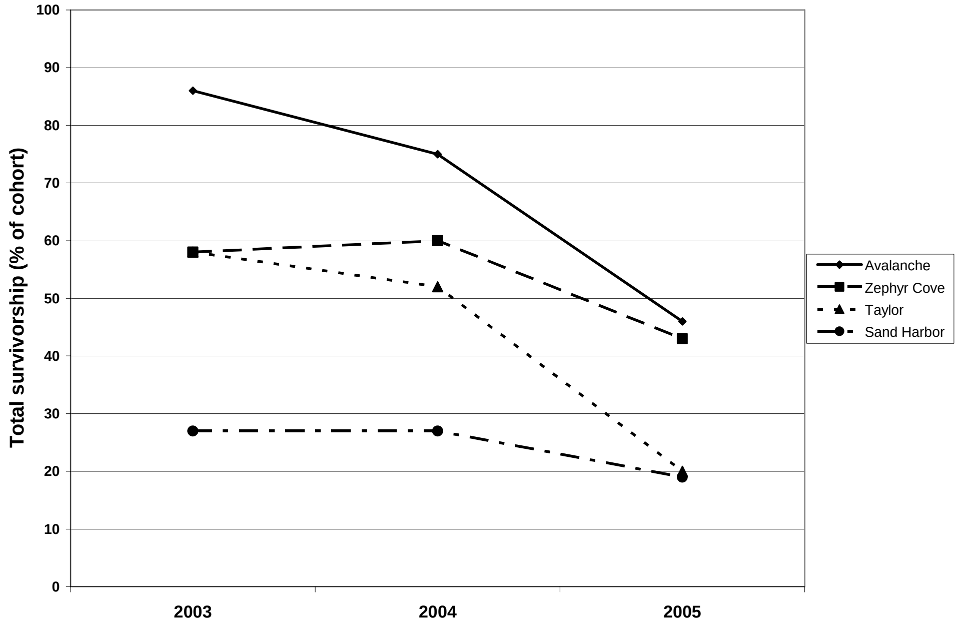


Figure 12. Overall survivorship of the 2003 cohort at four sites in September, 2003-2005.

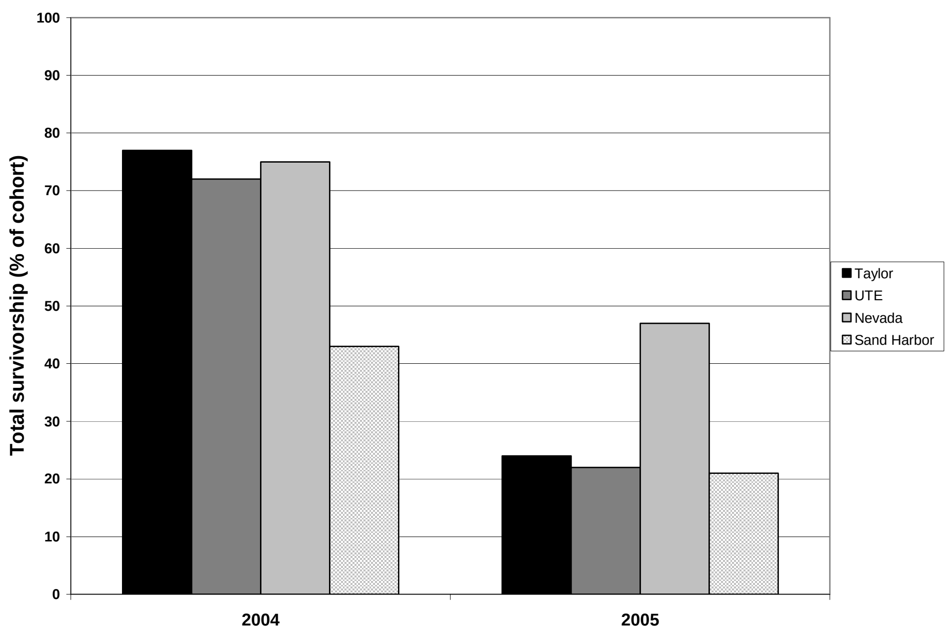


Figure 13. Overall survivorship of the 2004 cohort at four sites in September, 2004-2005.

The fact that approximately 20% of the 2003 and 2004 cohorts survived to reproduce despite fluctuating lake levels indicates that these outplantings are able to persist long enough to leave behind large numbers of offspring. Among the 2004 cohort, mean seed output per plant increased significantly during 2005 (see Figure 7). As discussed in section 3.4, the increase in lake elevation increased soil water availability to founders (as measured by higher xylem water potentials). With more moisture the two-year old surviving founders were probably able to produce and allocate more resources to growth and seed production. Likewise, the three-year old founders also experienced a slight increase in mean seed production after having experienced a decline during 2004.

3.7 Effects of disturbance

In 2005, all sites were partially or fully enclosed with fences except for Avalanche (the site was not fenced due to its isolated location). Fencing helped to reduce impacts from recreational activities among the sites, but several of the enclosures were vandalized during the season or damaged by storm waves or creek erosion.

At UTE, the permanent plastic-wrapped wire and wood post fencing along the eastern and southern perimeter of the enclosure remained intact throughout the season; however, the signage on the enclosure had badly deteriorated and most signs were ripped and illegible. Although footprints of dogs and humans were evident in the enclosure during every monitoring period, no wooden stakes were intentionally removed and it appeared unlikely that founder deaths could be attributed to vandalism. The disturbance from the rising lake eliminated the berm habitat that formed during 2004 and completely inundated the entire moist shoreline microhabitat.

Newly installed fences at Pope Beach and Ebright Beach were not vandalized or damaged and the reconstructed temporary fencing at Nevada Beach was also intact throughout the season. Temporary fencing constructed in the low beach at Zephyr Cove and at Taylor was not enclosed along the lake because of the higher lake elevation and sporadic inundation. Surviving individuals in these plots were subject to some trampling, primarily from dogs.

At Taylor Creek, the wire flags that marked translocated plants within the permanent fence were removed some time in July. Although the flags were replaced by biologists they were removed again in August. It was difficult to positively identify and remark transplants because of seedlings that established after the pilot was installed. The resulting uncertainty compromised our ability to interpret the translocation data with any confidence. Wooden stakes marking low beach habitat in the temporary fencing were also removed and strewn about the beach and some plants were intentionally pulled up. This plot had not been fully enclosed along the shoreline because of the fluctuating lake level, so it was easy to enter. The regular pattern of this plot made it easy to replace the stakes, but it was not possible to determine the exact number of plants that were pulled (probably less than 10).

The most severe effects of disturbance were at Hidden Beach. A storm in July damaged the temporary fencing as the lake inundated about half of the plot. Large amounts of woody debris and trash were deposited by stormwaves. The fence was soon repaired, but many of the founders had been washed away or covered completely with beach wrack. Survivorship at that site was only 5%, the lowest of any outplanting this year.

Fluctuating lake levels make for challenges in designing appropriate and effective fencing, however maintaining fencing throughout subsequent experimental and restoration plantings will be important for maintaining confidence in the data collected.

3.8 OVERALL SITE SUITABILITY

Overall site suitability must be inferred from performance of the 2003 and 2004 cohorts since the low quality of the 2005 cohort compromised results for this year. Among the 2003 cohort, overall survivorship was optimal in all years at Avalanche Beach (see Figure 12). Zephyr Cove experienced some first year losses from inundation, but survivors persisted and third year survivorship was nearly equivalent to Avalanche Beach. Both sites are probably mesic compared to Taylor Creek and Sand Harbor. The proportion of founders reproducing was uniformly high among the sites (between 77-100%), except among surviving founders in the dune trough at Taylor (27%). This microhabitat supported saturated soil conditions for most of the year that produced dense vegetation cover compared to the other sites. Total estimated seed production was greatest at Zephyr Cove (plant measurements were inadvertently not conducted at Avalanche Beach or Sand Harbor by agency personnel, so seed output estimates were not available for comparison) (Table 6).

Avalanche and Zephyr Cove provided excellent habitat during the low to transitional water conditions of the past three years. However, Zephyr Cove is mostly inundated in high water years and Avalanche also does not support plants in high water years. Of the four sites planted in 2003 (Avalanche, Zephyr Cove, Sand Harbor, and Taylor), Taylor Creek is the only site that has the diversity of microhabitats to consistently support plants in high water years (Appendix C, Pavlik and Stanton 2005). Some of these microhabitats are less then optimal in low water years, but they may provide upslope refuges in times of inundation. Although it was most difficult to get outplanted individuals established at Sand Harbor, the driest site with the warmest air temperatures, survivors did persist and reproduce reliably.

Table 6. Survivorship and reproductive output of the 2003 cohort at three sites in different microhabitats in September, 2005. (NA= not available. Data from Avalanche Beach were not collected).

Site and Habitat	Founders (# planted)	Survivorship (%)	Reproduction (%)	# plantlets	Mean canopy area (cm2/plant)	Mean seed output (per plant)	Total seed production (per cohort)
Taylor							
Moist shoreline	60	0.0	0.0	0			
Low Beach	240	17.9	93.0	186	157	526	18,420
Dune Trough	90	40.0	27.8	3	94	316	4,423
Zephyr							
Moist shoreline	60	0.0	0.0	47	0	0	0
Low Beach	96	51.0	77.6	174	311	1,104	39,759
High Beach	130	57.7	80.0	3	120	338	21,955
Sand Harbor							
Moist shoreline	80	1.3	100.0	0	NA	NA	NA
Low Beach	130	23.8	83.9	0			
High Beach	30	46.7	100.0	0			

Among the 2004 cohort, total first year survivorship was nearly equivalent at Taylor, UTE, and Nevada Beach while it was significantly reduced at Sand Harbor (see Figure 13). In 2005, inundation reduced survivorship among all sites, but Nevada Beach was less affected since founders were able to persist along the moist shoreline of Burke Creek. The proportion reproducing was more variable, ranging from a low of 25% in the moist shoreline at Nevada Beach, to a high of 99% in the high beach at Nevada (Table 7). Mean seed output per plant was greatest at Nevada Beach (1,130 seeds per plant) and similar between UTE and Taylor

Creek (621 and 728 seeds per plant, respectively). Seed output was not estimated at Sand Harbor. The greatest reproduction occurred with very large seed production (number of seeds output by a cohort) in the low beach at Nevada Beach, although mean seed output per plant was slightly higher in the low beach Taylor. Habitat at Taylor Creek has been heavily influenced by the creek itself over the last several years, whereas Burke Creek exerted little influence outside of the immediate shoreline. Compared to UTE, the higher seed out put in the low beach at Nevada Beach was likely due to a lack of competition from any competing vegetation, since the low beach habitat at UTE had very high lupine cover. Likewise, seed output was reduced in the dune trough habitat at Taylor Creek, which had relatively high cover of a variety of different species.

Table 7. Survivorship and reproductive output of the 2004 cohort at four sites in different microhabitats in September, 2005. (Seed output data from Sand Harbor was not available).

Site and Habitat	Founders (# planted)	Survivorship (%)	Reproduction (%)	# plantlets	Mean canopy area (cm2)	Mean seed output (per plant)	Total seed production
Taylor Creek							
Moist shoreline	45	0.0	0.0				
Low Beach	220	14.5	90.6	270	412	1,539	41,554
High Beach	60	88.3	81.1	0	141	425	21,247
Dune Trough	90	17.8	56.3	0	43	200	997
Sand Harbor							
Moist shoreline	71	0.0	0.0	0	NA	NA	NA
Low Beach	179	21.2	76.3	0			
High Beach	31	67.7	71.4	0			
Nevada Beach							
Moist shoreline	60	28.0	25.0	20	241	761	19,798
Low Beach	96	47.0	62.0	4	371	1,275	175,978
High Beach	130	48.0	99.0	1	294	965	68,478
Upper Truckee East							
Moist shoreline	250	0	0	0	0	0	0
Berm	250	0	0	0	0	0	0
Low Beach	250	33.2	93.8	0	223	816	58,745
High Beach	250	59.6	37.2	0	127	521	19,810
July High Beach	180	31.1	45.7	0	54	151	2,865
July Berm	180	0	0	0	0	0	0

3.9 TRANSLOCATION PILOT PROJECT

The translocation pilot project was compromised when the wire flags marking the transplants were removed by vandals for a second time in August. It was difficult to positively identify and remark the individuals because of the recruitment of natural seedlings subsequent to the installation. Three of the blocks were eliminated from analysis, leaving only 5 replicate blocks. Uncertainty remained over the identification of specific plants in the remaining five blocks so these individuals were also eliminated from analysis, lowering the total number of translocations from the original 56 to only 32. Consequently, it was not possible to evaluate the treatment of amending the soil with potting mix prior to planting, and only limited summary results are presented.

A total of 77% of the transplants apparently had survived until July 11, two weeks after translocation. By the time of the four week monitoring, the flags had been removed but it was still possible to relocate them. Total survivorship had risen to 87.5%, although some of the increase could be attributed to natural seedling recruitment. By the end of August, the flags had been removed again and total survivorship was estimated at 84%, or 27 of the identifiable 32 translocations.

Two months after the translocation it was difficult to visually determine which plots had received the soil amendment, and even with the compromise of the experiment, the treatment had no apparent effect. This treatment will not be pursued in 2006 in favor of other factors that likely have a greater effect on survivorship such as timing, watering regime, microhabitat, and site differences.

Despite the limited dataset, the apparent high survivorship indicates that it is possible to move plants within a site and that pursuing translocation as a potential mitigation strategy is warranted. Future efforts will need to more effectively protect experimental plots from vandalism through improved signage and develop a method for permanent marking.

4.0 DISCUSSION AND CONCLUSIONS

4. 1 KEY MANAGEMENT QUESTIONS

The Key Management Questions (KMQs) outlined in the CS guide conservation and restoration research on Tahoe yellow cress, meaning that generated data has immediate value to decision-making within an adaptive management framework (Pavlik and O'Leary 2002). Each section in the results of this report addresses aspects of the five KMQs, including the effects of lake elevation (KMQ 2) and initial founder vigor (KMQ3). Although lake elevation is perhaps the most critical determinant of the abundance and persistence of Tahoe yellow cress (Pavlik *et al* 2002a), it cannot be adjusted, only accommodated by management alternatives (e.g. prescriptions that change in high and low water years.

Unfortunately, the initial vigor of founding plants was very low in the 2005 cohort, resulting in lower survivorship and reproduction than expected (based on results from previous years). The large effect of poor initial founder vigor on demographic performance overwhelmed the other factors and compromised our ability to draw conclusions. Therefore, overall site suitability, microhabitat suitability, and time-specific variations must be inferred from second and third year performance of the 2004 and 2003 cohorts.

During 2005, an increase in lake level of nearly two feet had three main effects: 1) mesic, low elevation microhabitats (moist shoreline and berm) were fully inundated and founders were submerged if not destroyed, 2) the water status of founders in remaining, upslope microhabitats improved, and 3) founder performance in more xeric microhabitats (high beach) improved. Overall, there was probably more soil water available and two and three year-old founders that were not inundated experienced less stress than they had during 2004. The increased water availability apparently allowed founders (including those in the high beach) to produce and allocate more resources to both vegetative growth and seed production. The prolonged establishment period could have also contributed to increased seed output. However, while the 2004 cohort experienced large increase in seed production in the second year, there was not a comparable increase in seed output within the 2003 cohort in their second year (2004) when the lake level declined, indicating that water availability may have played a greater role in seed production than establishment period. The management implications of these effects of increasing lake level are that restoration efforts made during transitional lake elevations (e.g. 6,226) have a higher chance of succeeding in higher elevation beach microhabitats. This needs to be extended by testing performance of vigorous founders in previously unfavorable microhabitats (e.g. backdune, *Carex* meadow) that become more mesic during a high water year (e.g. above 6,226).

KMQ 1 and 2 address differences in overall habitat suitability among sites and the suitability of microhabitats within a given site, respectively. Data from the 2003 and 2004 cohorts demonstrated that, in general, survivorship varied among sites and within microhabitats. Across and within sites, survivorship and reproduction were highest in the mesic microhabitats (moist shoreline, berm, and low beach) and much lower in the high beach. However, the mesic microhabitats were also inundated during 2005, with submergence and/or destruction of founders. As predicted by the analysis in the CS, large amounts of optimal habitat are only available during low lake level years (< 6,224). However, during high water years, the rising water table reduces stress in formerly xeric, upslope microhabitats.

Overall site suitability, as indicated by demographic performance, supported the priority site rankings presented in the CS. Sand Harbor, a "Low Priority" site, had consistently poor performance during all years (2003-2005). Zephyr Cove, ranked "Medium Priority" in the CS, was subsequently revised to "High" in the 2004 ranking evaluation. Even though half of this site was inundated by the rising lake during 2005, vigorous, reproductive plants remained in upslope microhabitats. Performance of outplanted Tahoe yellow cress has been excellent in all three years at Avalanche Beach, an unranked site in the CS. The site is adjacent to Eagle Creek, a "High" priority site, and the two sites have been combined in recent versions of Appendix C of the TYC Annual Reports for ranking, survey, and management purposes. Taylor Creek, a "Core" site in the CS, had correspondingly high survivorship and reproductive output. First year survivorship of the 2004 cohort at UTE, also a "Core" site, and Nevada Beach, a "High" site, were uniformly high. Second year survivorship was highest at Nevada Beach, despite water stressed founders, because the site has a much steeper slope than UTE and less was inundated or disturbed by storm waves. It was not possible to assess differences in demographic performance and site rank among the other 2005 outplanting sites (Ebright Beach-Unranked, Pope Beach-Low, and Hidden Beach-Unranked) because of poor founder performance related to low initial vigor.

Differences in founder performance among the sites were likely related to several factors. Avalanche on the west side of the lake is the most mesic site, with late snow melt, and late afternoon shade that prevents beach sands from drying out over the summer. It also has the most difficult access and consequently the least recreational pressure. In contrast, Zephyr Cove, found on the drier east side of the lake, has warmer air temperatures, a coarser substrate, and greater recreational pressures. The lower performance of founders at this site, however, was probably due to inundation of the moist shoreline immediately after planting in 2003. The small increase in the number of plants at that site in 2004 was the result of vigorous vegetative reproduction and protective fencing that promoted recovery from disturbance. Taylor Creek, also a mesic site, experienced inundation during 2004 as a change in the course of the creek eroded away the entire moist shoreline plot. Sand Harbor is probably the driest site because of its location and exposure. Founders at this site had poor initial survivorship during 2003, likely because of high water stress from the hot, dry conditions. However the site was also inundated by lake level and strong waves during 2003, which was the single greatest source of mortality during the first phase of reintroduction. Although all sites were inundated during 2005, only Taylor Creek and Upper Truckee East have a variety of microhabitats that permits founders to persist in both low and high water years.

KMQ 3 addresses those factors that influence the success of outplanting and, therefore, determines the feasibility of creating or enhancing populations as a restoration tool. The fact that approximately 20% of the 2003 and 2004 cohorts survived to reproduce despite fluctuating lake levels indicates that founders are able to persist. Large and significant increases in reproductive output by two and three year-olds across all sites indicate that age-structured enhancements have a high potential for self-sustainability. The observed increase in water availability may have been chiefly responsible for increases of reproductive output in two and three year-olds during 2005 (since no similar increase was observed between 2003 and 2004,). Older and larger plants (above and/or below ground) may offer more resilience to disturbance or resistance to pathogens or invasive plant species. In addition, three successive years of outplantings at the same sites have yielded markedly different levels of demographic performance, giving support to the concept of spreading the risk of founder investment across years using "founder cost-averaging". This strategy can help minimize losses from fluctuating lake elevations. Finally, although results from the translocation experiment were limited, the data indicate that it is possible to successfully move plants within a site and that pursuing translocation as a potential mitigation tool is warranted.

KMQ 4 addresses the importance of using multiple seed source populations in restoration efforts. Although the amount of data was limited, there was some evidence of superior performance of one seed source among the 2005 cohort at one site (UTE founders at Nevada Beach). Seed source was not found to have a significant effect on survivorship or reproduction during 2004 when both the quality of the founding cohort and the experimental data were robust. Still, it is not possible to strictly rule out the influence of genetic factors and it will be necessary to repeat the 2005 experimental design in another year (e.g. 2006). Until data suggest otherwise it would be appropriate to mix seed from many source populations for restoration purposes to install any unique alleles in founding cohorts.

Finally, KMQ 5 focuses on disturbance from recreation, vandalism, or intense shoreline activity. Fencing helped to reduce impacts from recreational activities among the sites, but several enclosures were vandalized during the season or damaged by storm waves or beach erosion. Future efforts will need to more effectively protect experimental plots and develop a method for permanent marking that is less susceptible to vandalism.

5.0 RECOMMENDATIONS FOR 2006

The low quality of container-grown Tahoe yellow cress founders compromised the experimental and restoration outplantings during 2005. Therefore, the most important factor in the success of future outplantings will be to ensure the high quality of plants propagated by the nurseries. This will require close oversight and coordination with nursery personnel on a regular basis. Coordination with Sierra Valley Farms has been sufficient in the past, but plants should be transported directly to the Tahoe basin prior to the 2006 outplanting, rather than to Washoe Valley Nursery. Coordination with Washoe Valley needs improvement and could benefit from developing an agreement for TAG oversight of the project, including regular visits during the growing season. Propagated plants should be evaluated for initial vigor on a more objective, less relative scale than was employed during 2005 to more fully separate propagation effects on demographic performance from experimental variables such as microhabitat or population seed source.

A second important factor that compromised portions of the research effort was vandalism. Site protection may require better signage, not only on the exterior of enclosures but also directly within or next to experimental plots. For example, a simple sign that kids could easily read placed directly in a plot that states "Earth healing in progress. Please do not remove stakes, tags, or plants" might lend an air of importance to the project and deter vandalism. However, if signage fails to deter people from entering the plots it may be necessary to develop patrol and enforcement actions.

In conjunction with adequate signage, public outreach efforts should be implemented to educate the public on the benefits of the project. Various media sources indicate widespread support among visitors and residents for protecting the resources of Lake Tahoe. A media event at the time of outplanting that focuses on the role of research and management efforts in the protection of Tahoe yellow cress and Lake Tahoe itself could help raise the profile of the project and foster greater understanding and support.

The experimental reintroduction at UTE and Nevada Beach will need to be repeated again to test and extend the conclusions from the 2004 results. Although first year performance among the 2005 cohort was compromised, second year results obtained during 2006 can still be compared to second year results from the 2003 and 2004 cohorts. All results can be interpreted in terms of low lake levels in 2003- 2004 and transitional lake levels in 2005. A high lake level during 2006 would provide a broad spectrum of data from which alternative restoration prescriptions could be crafted. In the event of high water, the premium of available habitat may force alterations to some design elements; however, it will be critical to retain as much replication as possible to provide the best comparisons of demographic performance in different hydrological years.

The limited results from the translocation experiment indicate that it is possible to successfully move plants within a site and that pursuing translocation as a potential mitigation tool is warranted. Lake elevation is likely one of the most critical determinants of success, making the timing and microhabitats of the translocation important factors. Translocation should be tested on a monthly basis within the current approved survey window for Tahoe yellow cress of June 15 –September 15. Elevation above lake level (i.e. microhabitat/topography/hydrology) should also be incorporated into the tests, moving plants between similar and different positions along a transect. If sufficient plants are available, it would be good to test different transplantation techniques, including different methods for retaining roots and watering during the early phases of establishment.

Further expansion of the hydrological monitoring to more sites, including naturally occurring individuals at sites that are not outplanted, could provide a better picture of differences in water availability around the lake. Expanding the monitoring within a site to include the entire moisture gradient would further refine the hydrological parameters of optimal microhabitat.

Finally, the AMWG could pursue other research opportunities that would inform TYC management, such as dispersal, seed bank dynamics and rootstock longevity. A potential collaboration is currently developing with the University of Nevada at Reno to examine dispersal among TYC subpopulations using microsatellite DNA analysis techniques. A microsatellite is a short block of DNA sequence, often less than 150 base pairs long, that is repeated many times within the genome of an organism. Many repeats tend to be concentrated at the same locus and the number of repeats at a particular locus is hypervariable (highly polymorphic) between individuals of the same species. By looking at the variation of microsatellites among individuals in a population, inferences can be made about dispersal events (i.e. where the population originated), population structure, genetic drift, genetic bottlenecks and even the date of a last common ancestor. Microsatellites can be used to detect sudden changes in population, effects of population fragmentation, the interaction of different populations, and are useful in the identification of new and incipient populations. This avenue of research could yield valuable insight into the metapopulation dynamics of Tahoe yellow cress.

6.0 LITERATURE CITED

CSLC (California State Lands Commission). 1998. Biological assessment for Tahoe Yellow Cress. CSLC, Sacramento, CA.

Carlsen, T.M., J.W. Menke and B.M. Pavlik. 2000. Reducing competitive suppression of a rare annual forb by restoring native perennial grasslands. Restoration Ecology 8, 18-29.

DeWoody, J. and V.D. Hipkins. 2004. Expanded evaluation of genetic diversity in Tahoe yellow cress (*Rorippa subumbellata*). USDA, Forest Service, National Forest Genetic Electrophoresis Laboratory. Placerville, CA.

DeWoody, J. and V.D. Hipkins. 2006. Genetic Monitoring of *Rorippa subumbellata* (Tahoe yellow cress): Analyzing Northeast Populations and Monitoring South Shore Populations. USDA, Forest Service, National Forest Genetic Electrophoresis Laboratory Project #194. Placerville, CA.

Falk, D.A. and K. E. Holsinger. (eds.) 1991. Genetics and Conservation of Rare Plants. Oxford University Press, New York.

Fiedler, P.L. 1991. Mitigation-related transplantation, relocation and reintroduction projects involving endangered, threatened and rare plant species in California. California Department of Fish and Game, Endangered Plant Program, Sacramento, CA.

Fiedler, P.L. and R. Laven. 1996. Selecting reintroduction sites. In: Falk, D., C. Millar and P. Olwell (eds.) Restoring Diversity. Strategies for Reintroduction of Endangered Plants. Island Press, Washington, D.C. pp. 157-170.

Guerrant, E.O. Jr. and B. M. Pavlik. 1997. Reintroduction of rare plants: Genetics, demography and the role of *ex situ* methods. In: P.L. Fiedler and S.K. Jain (eds.) Conservation Biology: The Theory and Practice of Nature Conservation, Preservation and Management. Second Edition, Chapman and Hall, London. pp 80-108.

Pavlik, B. M. 1987. Autecological monitoring of endangered plants. (In T. Elias, ed.) Rare and Endangered Plants: A California Conference. Proceedings of the Symposium. California Native Plant Society Special Publication 8, 385-390. Sacramento, CA.

Pavlik, B.M. and M.G. Barbour. 1988. Demographic monitoring of endemic sand dune plants, Eureka Valley, California. Biological Conservation 46, 217-242.

Pavlik, B.M., N. Ferguson, and M. Nelson. 1993. Assessing limitations on the growth of endangered plant populations. II. Seed production and seed bank dynamics of *Erysimum capitatum* ssp.*angustatum* and *Oenothera deltoides* ssp. *howellii*. Biological Conservation 65, 267-278.

Pavlik, B.M. and E. Manning. 1993. Assessing limitations on the growth of endangered plant populations. I. Experimental demography of *Erysimum capitatum* ssp. *angustatum* and *Oenothera deltoides* ssp. *howellii*. Biological Conservation 65, 257-265.

Pavlik, B.M., D.Nickrent and A. Howald 1993. The recovery of an endangered plant. I. Creating a new population of *Amsinckia grandiflora* . Conservation Biology 7, 510-526.

Pavlik, B.M. 1994. Demographic monitoring and the recovery of endangered plants. In: Bowles, M. and C.Whalen (eds.) Restoration of Endangered Species. Blackwell Scientific, London. pp. 322-350.

Pavlik, B.M. 1995. The recovery of an endangered plant II. A three-phased approach to restoring populations. In: Urbanska, K.M. and K. Grodzinska (eds.) Restoration Ecology in Europe. Geobtanical Institute SFIT, Zurich, Switzerland. pp. 49-69.

Pavlik, B.M. 1996a.Conserving plant species diversity: The challenge of recovery. In: Szaro, R.C. and D.W. Johnston (eds.) Biodiversity in Managed Landscapes - Theory and Practice. Oxford University, New York. pp. 359-376.

Pavlik, B.M. 1996b. A framework for defining and measuring success during reintroductions of endangered plants. In: Falk, D., C. Millar and P. Olwell (eds.) Restoring Diversity. Strategies for Reintroduction of Endangered Plants. Island Press, Washington, D.C. pp. 127-156.

Pavlik, B.M. 1997. Approaches, techniques and institutions for conserving rare plants. Southwest Naturalist 4, 375-383.

Pavlik, B.M. and E.K. Espeland. 1998. Demography of natural and reintroduced populations of *Acanthomintha duttonii*, an endangered serpentinite annual in Northern California. Madrono 45, 31-39.

Pavlik, B. M. (2001). Developing an ecosystem perspective from experimental monitoring programs II. Physiological responses of a rare geothermal grass to soil water. Environmental Management 28, 243-253.

Pavlik, B.M. and A. Enberg. (2001). Developing an ecosystem perspective from experimental monitoring programs: I. Demographic responses of a rare geothermal grass to soil temperature. Environmental Management 28, 225-242.

Pavlik, B., D. Murphy, and Tahoe Yellow Cress Technical Advisory Group. 2002a. Conservation Strategy for Tahoe Yellow Cress (*Rorippa subumbellata*). Tahoe Regional Planning Agency. Stateline, NV.

Pavlik, B., A. Stanton, and J. Childs. 2002b. Implementation of the Conservation Strategy for Tahoe Yellow Cress (*Rorippa subumbellata*): I. Seed Collection, Assessment of Reproductive Output, and Propagation for Reintroduction.

Prepared for the Tahoe Yellow Cress Technical Advisory Group and the Tahoe Regional Planning Agency. Zephyr Cove, NV.

Pavlik, B., and A. Stanton. 2004. Implementation of the Conservation Strategy for Tahoe Yellow Cress (*Rorippa subumbellata*): III. Pilot Project to Support Reintroduction Experiments. Prepared for the Tahoe Yellow Cress Technical Advisory Group and the Tahoe Regional Planning Agency. Stateline, NV.

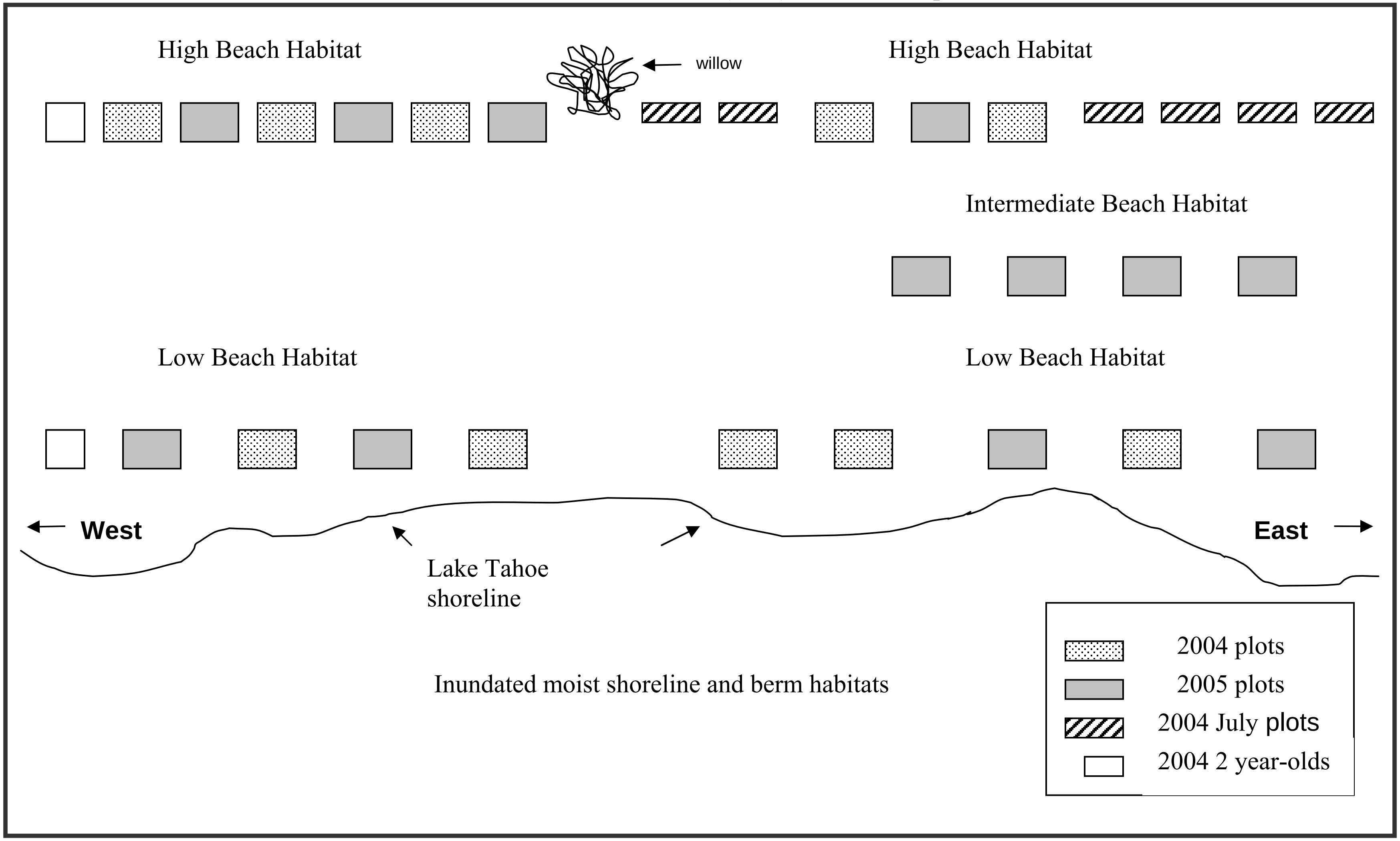
Pavlik, B., and A. Stanton. 2005. Implementation of the Conservation Strategy for Tahoe Yellow Cress (*Rorippa subumbellata*): IV. Experimental Reintroductions: Year One. Prepared for the Tahoe Yellow Cress Technical Advisory Group and the Tahoe Regional Planning Agency. Stateline, NV.

Reed, S. 1982. Sensitive Plant Interim Management Prescription for *Rorippa Subumbellata*, Roll. USDA, Forest Service, Lake Tahoe Basin Management Unit. South Lake Tahoe, CA.

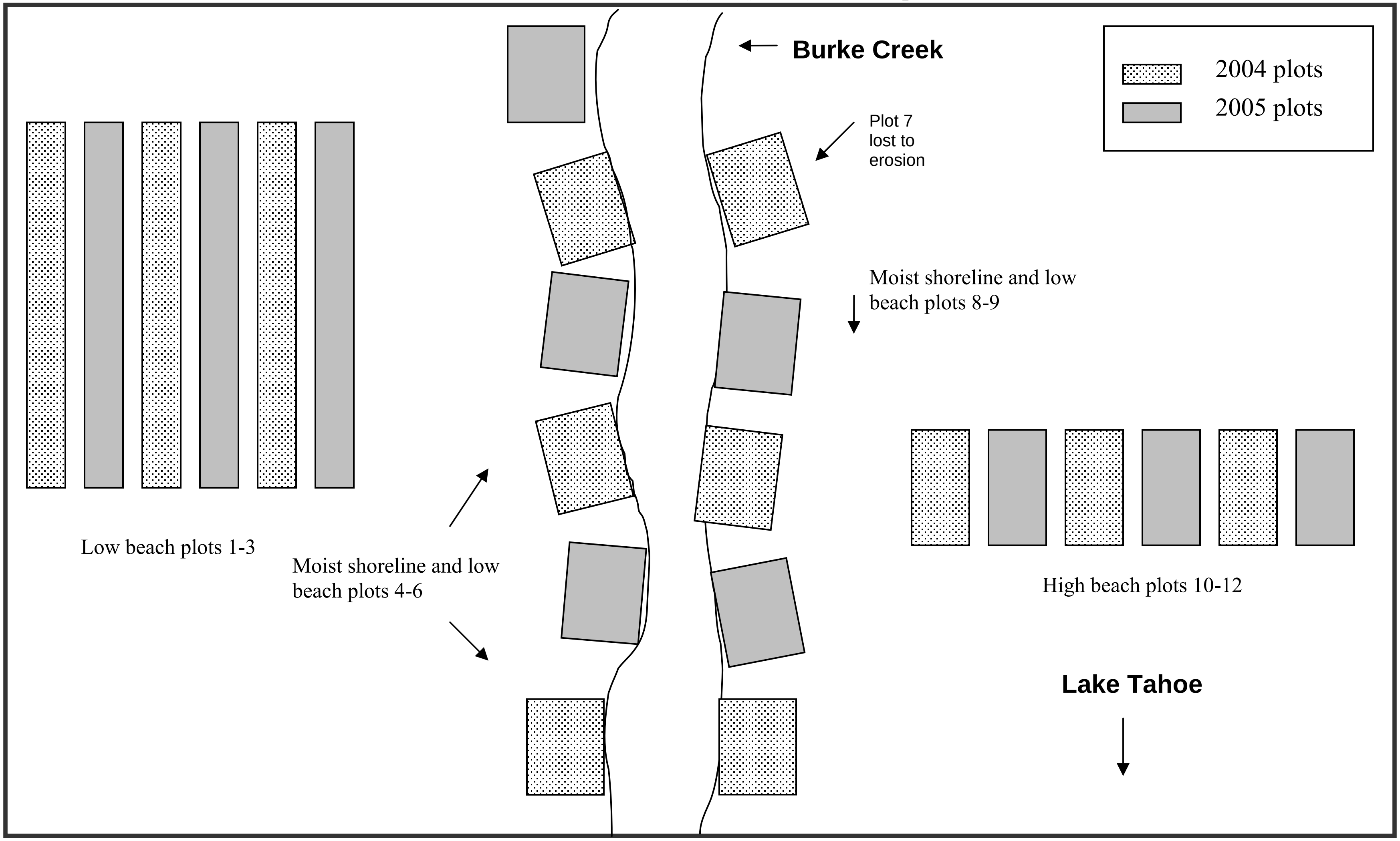
Saich R.C. and V.D. Hipkins. 2000. Evaluation of genetic diversity in Tahoe yellow cress (*Rorippa subumbellata*). USDA, Forest Service, National Forest Genetic Electrophoresis Laboratory. Camino, CA.

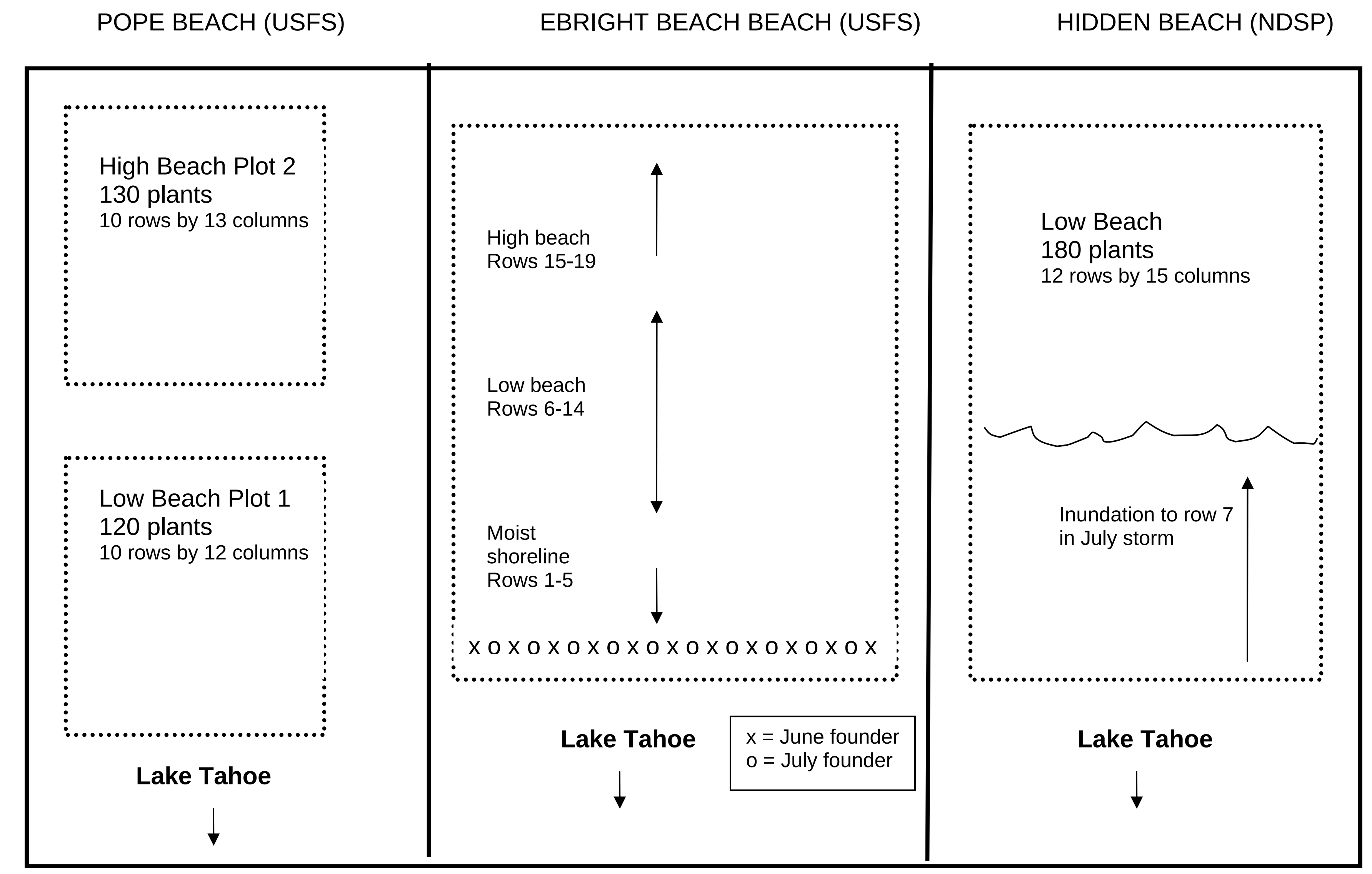
APPENDIX A SITE MAPS

UPPER TRUCKEE EAST (CTC) 2005 Site Map



NEVADA BEACH (USFS) 2005 Site Map




POPE BEACH (USFS)
EBRIGHT BEACH BEACH (USFS)
HIDDEN BEACH (NDSP)
High Beach Plot 2
130 plants
10 rows by 13 columns
Low Beach Plot 1
120 plants
10 rows by 12 columns
Lake Tahoe
High beach
Rows 15-19
Low beach
Rows 6-14
Moist
shoreline
Rows 1-5
x o x o x o x o x o x o x o x o x o x o x
Lake Tahoe
x = June founder
o = July founder
Low Beach
180 plants
12 rows by 15 columns
Inundation to row 7
in July storm
Lake Tahoe

APPENDIX B PHOTOS

Photo 1. View to the west at Upper Truckee East, showing the enclosure in a) August 2004 and b) July 2005.

a)

b)

Photo 2. Moist shoreline habitat at Upper Truckee East in a) August 2004 and b) July 2005.

a)

b)

Photo 3. Berm habitat at Upper Truckee East in a) August 2004 and b) July 2005.

a) **b)**

Photo 4. Low beach habitat at Upper Truckee East in July, 2005.

Photo 5. Container–grown TYC showing senescent low vigor individual with new root development.

Photo 6. Dune trough habitat at Taylor Creek in July of a) 2003 and b) 2005.

a) **b)**

Photo 7. The enclosure in low beach habitat showing inundation from Taylor Creek in July, 2005.

Photo 8. The enclosure at Nevada Beach showing a) low beach and b) moist shoreline habitat along Burke Creek in June, 2005.

a)

b)

Photo 9. An outplanted TYC underwater in Burke Creek at Nevada Beach in June, 2005.

Photo 10. One of two new pressure bombs purchased in in 2005.

Photo 11. The translocation at Taylor Creek with a) a two or three year-old outplanted founder, b) re-planting, c) seven outplanted founders in pots awaiting tranlocation and d) another translocation .

a) **b)**

c)

Photo 12. Low beach habitat at Avalanche Beach in June, 2005.

d)

Photo 13. The partial, temporary enclosure in the low beach at Zephyr Cove in July, 2005.

Photo 14. The enclosure at Hidden Beach during planting in June, 2005.

Photo 15. Temporary enclosure in the low beach and high beach at Pope Beach in June, 2005.