Implementation of the Conservation Strategy for Tahoe Yellow Cress
(*Rorippa subumbellata*)

IV. Experimental Reintroductions, Year One

Prepared for the

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Executive Summary

We present results of the first year of experimental reintroductions of Tahoe yellow cress ((TYC, *Rorippa subumbellata*), a plant endemic to the shores of Lake Tahoe. Reintroduction is specified in the Conservation Strategy (Pavlik et al 2002a) as a potentially valuable tool in efforts to restore and manage the species. This report and three others (Pavlik and Stanton 2004, Pavlik et al. 2002b, Pavlik and O'Leary 2002) address efforts to advance two of the Conservation Goals of the CS to 1) improve the size and persistence of TYC populations at core and priority restoration sites and 2) conduct research that directly supports management and restoration activities.

Beginning in May of 2004, we worked with agency landowners to install protective fencing and over 2,800 container-grown TYC plants at four sites around the lake's southern and eastern perimeter. Two sites (Upper Truckee East and Nevada Beach) were new and two of the sites (Taylor Creek and Sand Harbor) had been planted in 2003. The 2003 pilot outplanting project included an outplanting of over 1,4oo container- grown plants at four sites (Pavlik and O'Leary 2002, Pavlik and Stanton 2004). Information from the pilot project on such factors as nursery propagation procedures, fencing, working with agency personnel, permit compliance, and outplanting and monitoring techniques has greatly informed the 2004 experiments.

The 2004 project had four major components: 1) the replicated, experimental reintroductions at Upper Truckee East and Nevada Beach with demographic monitoring 2) replication of the 2003 pilot design at Taylor Creek and Sand Harbor with demographic monitoring, 3) continued demographic monitoring of the 2003 outplanted cohort ("two year-olds"), and 4) water relations monitoring of the 2003 and 2004 outplanted cohorts.

The 2004 experimental reintroduction utilized a hypothesis-driven, replicated design to address all 5 of the Key Management Questions (KMQs) that guide conservation and restoration research on TYC (Pavlik and O'Leary 2002). The KMQs are intended to implement the CS by focusing research that is of immediate value to decision-making within an adaptive management framework. Results from year 1 of the experimental reintroduction provided preliminary answers for all 5 of the KMQs as presented in the following table:

Key Management Questions for guiding conservation and restoration research on Tahoe Yellow Cress

Can TYC populations occupy any site around the lake margin that has sandy beach habitat?

No, the results to date suggest that TYC performance is excellent at some sites and poor at others. Managers cannot, therefore, assume site equivalency when issuing permits or prescribing mitigation measures that affect the species.

Are there ecosystem factors that can affect TYC performance within an occupied site or microhabitat?

Yes, ecosystem factors affect TYC performance. The main ecosystem factor tested in the reintroduction experiments was depth to the water table within different microhabitats. Microhabitats that provide a shallow depth to the water table that are protected from lake level and human disturbance are more likely to allow high survivorship and reproductive output of TYC. Managers cannot, therefore, assume microhabitat equivalency when issuing permits or prescribing mitigation measures that affect the species.

Can TYC populations be created or enlarged in order to restore the self-sustaining dynamics of the species?

Yes, founders outplanted in 2003 persisted in 2004, suggesting that reintroduction to certain microhabitats at a given sandy site appears to be a practical and effective tool for creating or enhancing TYC populations. Managers can, therefore, prescribe carefully designed, executed, and monitored reintroduction for purposes of conservation, restoration and mitigation.

Can any TYC genotype perform equally well at any appropriate site?

Yes, the genotype of a source population had no significant effect on TYC performance. Therefore, managers do not have to insist on certain design features to compensate for genetic factors when reintroduction is for conservation, restoration or mitigation.

Can TYC microhabitats/places be found or created that are less likely to be adversely disturbed despite high visitor use or intense shoreline activity?

Yes, fencing is mostly effective for protecting TYC conservation and restoration projects. Therefore, managers will need to maintain fencing during all conservation, restoration, and mitigation projects, especially those that require collection of monitoring data.

Replication of the 2003 pilot design at Taylor Creek and Sand Harbor was meant to test the ideas of age-structured outplanting and "founder–cost averaging". The age-structure of a rare plant population may be important for the maintenance of high levels of reproductive output. "Founder-cost averaging" is the successive outplanting of founders of any age class in different years. Continued monitoring of the 2003 cohort enabled a comparison of the effects of changing lake level on microhabitat characteristics and demographic performance of TYC. The persistence and reproductive output of 2003 founders was also used to evaluate success in creating new populations or enhancing existing ones. Results indicate that both age-structure and founder-cost averaging are effective tools for reintroducing and enhancing populations of Tahoe yellow cress.

In 2005, the experimental reintroductions at Upper Truckee East and Nevada Beach will be replicated. Monitoring of the pilot project sites will continue and additional sites may be outplanted to test specific restoration hypothesis. A translocation component, involving relocating outplanted founders both within and among sites, will be added to test possible mitigation options.

1.0 Introduction

The overall purpose of the Conservation Strategy (CS) for Tahoe Yellow Cress (TYC, *Rorippa subumbellata*) is to restore a self-sustaining metapopulation dynamic that allows the species to persist in sandy beach habitat around Lake Tahoe despite high water levels and recreational impacts (Pavlik et al. 2002a). This report and three others (Pavlik and Stanton 2004, Pavlik et al. 2002b, Pavlik and O'Leary 2002) address efforts to advance 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 Questions (KMQs) that guide conservation and restoration research on TYC (Pavlik and O'Leary 2002) are intended to implement the CS by focusing research that is of immediate value to decision-making within an adaptive management framework. While the 2003 Pilot Project outplanting design was site-specific, lacked replication, and addressed pilot objectives rather than KMQs, the 2004 experimental reintroduction utilized a hypothesis-driven, replicated design to address all 5 of the KMQs. Information gained from the 2003 pilot project on nursery propagation, fencing, agency personnel, permit compliance, and techniques for outplanting and monitoring greatly informed the 2004 experiments.

Beginning in May of 2004, we worked with agency landowners to install over 2,800 plants at four sites around the lake's southern and eastern perimeter. Two sites (Upper Truckee East and Nevada Beach) were new and two of the sites (Taylor Creek and Sand Harbor) had been planted in 2003. Demographic and water relations monitoring were refined in 2004 to better determine microhabitat conditions and best management practices that optimize the chances for successful restoration of TYC.

The 2004 project had four major components: 1) the replicated, experimental reintroductions at Upper Truckee East and Nevada Beach with demographic monitoring 2) replication of the 2003 pilot design at Taylor Creek and Sand Harbor with demographic monitoring, 3) continued demographic monitoring of the 2003 outplanted cohort ("two year-olds"), and 4) water relations monitoring of the 2003 and 2004 outplanted cohorts.

Experimental reintroduction is a management tool used to address KMQs. The replicated design with "cause and effect" monitoring provides statistical power to evaluate factors central to those questions : 1) the effects of microhabitat, founder seed source, founder vigor, and founder water status on survivorship and reproduction, 2) the effect of outplanting timing on demographic performance, and 3) the efficacy of precision seeding to enhance or create TYC populations. In this way research hypotheses are only tested if the results immediately benefit implementation of the CS, as discussed in section 4.1 of this report.

Replication of the 2003 pilot design at Taylor Creek and Sand Harbor was meant to test the ideas of age-structure outplanting and "founder–cost averaging". The age-structure of a rare plant population may be important for the maintenance of high levels of reproductive output (seeds and clones). Building an optimized age-structure in reintroduced populations can be accomplished by planting multiple age classes (e.g. one year-olds, two year-olds, etc.) in a single year or by promoting survival of founders across years. Members of different classes often differ in size and, therefore, in resources available for reproduction. Presumably, older and larger founders would produce more seeds or clones than younger, smaller founders, and could boost the overall production of new plants in a given year. "Founder-cost averaging" is the successive outplanting of founders of any age class in different years. In this way the risk of outplanting all founders in an unfavorable year (e.g. drought, high lake level) is reduced. This minimizes stochastic effects and is analogous to "dollar-cost averaging" in financial investment. Instead of maximizing monetary return, this ecological restoration technique could be used to maximize "return"(survival and reproductive output) on the investment of founders among all outplanting years.

Continued monitoring of the 2003 cohort (referred to as "two year-olds') enabled a comparison of the effects of changing lake level on microhabitat characteristics and demographic performance of TYC. The persistence and reproductive output of 2003 founders can be used to evaluate success in creating new populations or enhancing existing ones.

Finally, a refined physiological monitoring technique was used to make inferences about the relationship of founder survivorship or reproduction with plant water status (measured as xylem water potentials). Correlation between demographic performance and water status would enable predictions about the probability of successful restoration based on microhabitat characteristics related to hydrology or microclimate.

2.0 Methods

2.1. Nursery Propagation of Founders

2.1.1. Seed Collection

Seeds were collected in September 2003 at 9 core and priority restoration sites: Blackwood North, Blackwood South, Cascade, Lighthouse, Tallac Creek, Taylor Creek, Regan Al Tahoe, Tahoe Meadows, and Upper Truckee East. Seeds from the two Blackwood sites were combined for outplanting purposes. All seed collections were cleaned and hand-sorted into two equal lots by December and stored in manila envelopes at room temperature and humidity. Seed lots were delivered to two native plant nurseries in the spring.

As part of the ongoing founder propagation necessary for an age-structured reintroduction, additional seeds were collected in September 2004. The 2004 seeds were stored at room temperature and humidity in dry manila envelopes, to be sorted and planted during the summer of 2005.

2.1.2. Nursery Propagation

Two nurseries renewed contracts with the USDA Forest Service to propagate TYC: the USDA Forest Service facility (operated by the Nevada Division of Forestry) at an elevation of 5,000 ft in Washoe Valley, NV; and privately-owned Sierra Valley Farms at an elevation of 5,000 ft in Beckwourth, CA, 25 miles north of Truckee. Both facilities propagated TYC for the 2003 pilot project and followed the same propagation protocols designed to maximize yield of founders while minimizing artificial selection and *ex situ* loss of genetic variation. The objective was to raise hardy, rather than productive, founders that would survive transplanting. For further details see the previous report in this series (Pavlik and Stanton 2003).

The nurseries were directed to utilize all seed lots and plant a minimum of 2,400 plants in plastic supercells with standard greenhouse soil-less potting mix. One to two inches of Lake Tahoe beach sand were sprinkled on the surface to cover the seeds. The seed source of each propagule was tracked in order to estimate fitness components (e.g. seed output - plant size correlations) and evaluate the performance of different reintroduced populations.

2.2. Site Selection

2.2.1. 2003 Pilot Study Sites

Four sites were planted for the 2003 pilot project; Avalanche beach in Emerald Bay (California Department of Parks and Recreation), Taylor Creek at Baldwin Beach (US Forest Service), Zephyr Spit at the Zephyr Cove Resort (US Forest Service), and Sand Harbor (Nevada Division of State Parks). Site selection was based on a combination of the following factors: 1) sites subjectively resembled "typical" TYC microhabitats, having the ecological characteristics described in the CS (pgs. 20-26) 2) the agency landowner could make an in-kind contribution of personnel for outplanting and monitoring 3) at high use sites, the agency could install fencing to protect the founders from human disturbance 4) the reintroduction and any associated fencing could comply with CEQA or NEPA, 5) the installation was compatible with the recreational patterns on the beach. In addition, it was desirable that the four selected sites span the west-east (mesic to xeric) microclimate gradients described in the CS (pg. 20). Descriptions of these sites may be found in the 2003 pilot project report (Pavlik and Stanton 2003).

2.2.2. 2004 Experimental Reintroduction Sites

Two new sites were selected in 2004 for installation of experimental plots; Upper Truckee East on the eastern side of the Upper Truckee River at Barton Meadow (California Tahoe

Conservancy) and Nevada/Kahle Beach, north of Edgewood golf course (US Forest Service). 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 design in at least two microhabitats. Both sites are described below.

2.2.2.1. 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. Over 13,600 stems were counted at UTE during the annual survey in September 2003.

TYC habitat has been protected at the site with a fence that extends towards the lake from the edge of the meadow that limits beach access on the east side of the population (Photo 1). A second fence runs parallel to the shore between the meadow and the high beach, allowing user access along meadow. Signs along the lake side that designate habitat are moved as the lake recedes, 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 vast expanses of sandy sediment. Depending on the year, the lake shoreline can recede several hundred meters from where it was present at the beginning of the season. In 2004, the moist shoreline, saturated in May and June, became gradually filled in with grass (*Agrostis)*, fireweed (*Epilobium*), and monkeyflower (*Mimulus*) and generally did not support many TYC individuals (Photo 2). The Upper Truckee River deposits large amounts of sediment in the lake and consequently, sandy berms formed adjacent to moist shoreline. These berms were elevated by one or two feet above the water and supported dense amounts of TYC with little competition from other plant species (Photo 3). One the other side of the moist shoreline, a wet depression stretched the length of the beach forming a long trough that was saturated early in the season. The trough contained many new willow sprouts, thick swards of grass, sedges, and tiny rushes and did not support TYC. Upslope from the trough, the low beach habitat was sandy and open, with scattered lupines that became very dense as the season progressed (Photo 4). High beach habitat extended to the stabilized dune and was very sandy and largely free of vegetation cover (Photo 5).

2.2.2.2. 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. Only one naturally occurring TYC plant was present in 2004 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 new, temporary fencing extends 20m from the old fence, leaving an access corridor of about 12m between the fence and Lake Tahoe. Although moist shoreline habitat 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. Both low and high beach habitats are present upslope in the coarse sandy beach that is completely free of vegetation cover.

2.3 Habitat Factors Affecting the 2004 Experimental Reintroduction

2.3.1. Lake Level

The first outplanting of 2004 was conducted in early summer, beginning on May 24th and ending on June 3rd. The lake level on May 25th (6,224.2 ft) continued to rise over the next 10 days to 6,224.3 ft on June 3rd, the highest of the season, which was maintained for several weeks (Figure 1). In mid-June, the lake began a slow recession, dropping to a season low of 6,222.6 ft on October 16th. The lake was at 6,223.9 ft at the time of the second outplanting at Upper Truckee on July 29th.

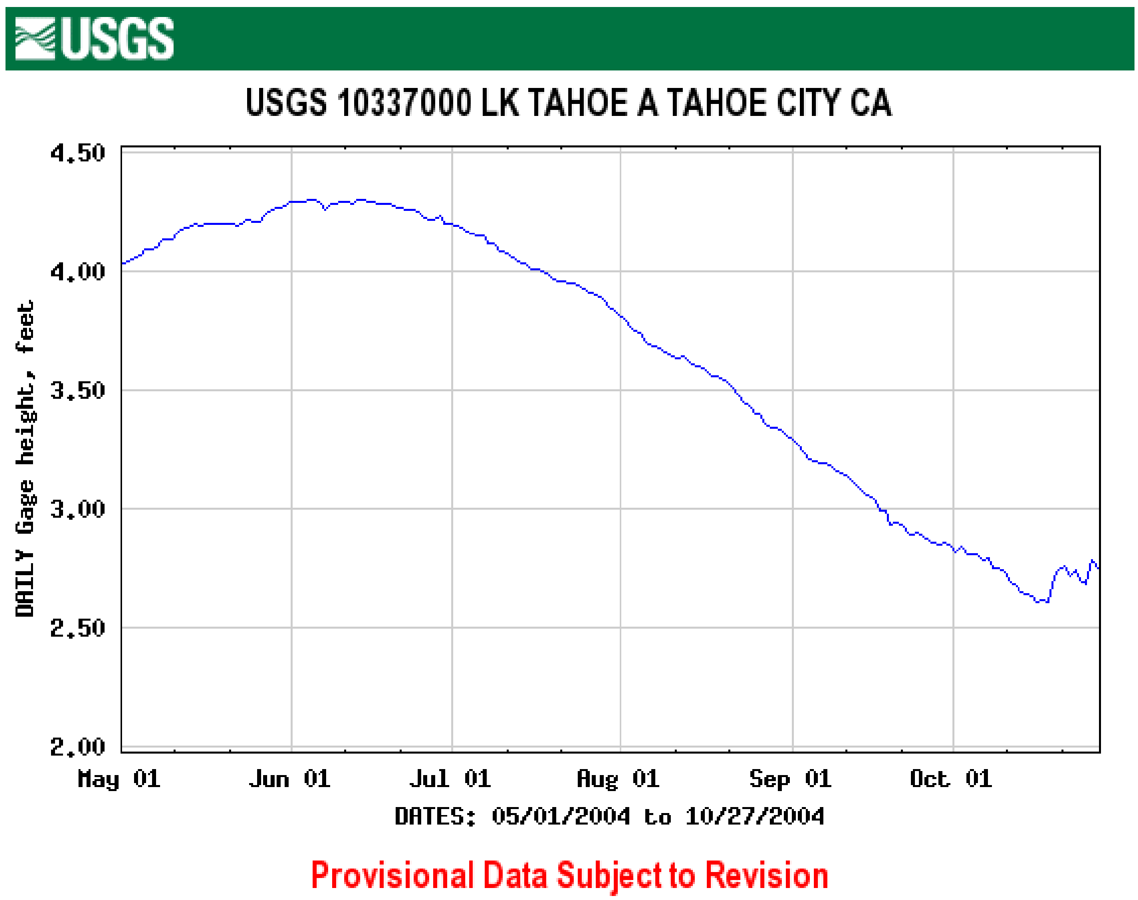


Figure 1. Elevation of Lake Tahoe showing yearly peak in June and low in October 2004 (add 6,220 ft LTD to gage height on the y axis). Graph from the USGS Tahoe City station.

2.3.2. TYC Microhabitats

Tahoe yellow cress occurs only around Lake Tahoe within a narrow elevation range (6,222 - 6,230 ft), on gently sloping beaches that have nearly 360^{o} exposure. The main macroclimatic determinant of site variations is the west-to-east precipitation gradient that exists in the basin (Pavlik et al. 2002a). The Sierra rainshadow makes for wet conditions on the west shore and arid conditions on the east shore. At Tahoe City along the west shore, mean annual precipitation is 32 in (80.6 cm) while at Glenbrook along the east shore it is only 19 in (47.4 cm).

The CS identified nine distinctive Tahoe yellow cress microhabitats that occur on the shores of Lake Tahoe. Defined by geomorphology, elevation, and other environmental factors, the nine include: low beach, sand bars, berms, rock shelters, barrier beaches, high beach, back beach depressions, meadows, and dunes. These designations did not capture all of the variation at the outplanting sites, so each was evaluated using microtopographic measurements. A laser level was used to determine the elevation of each experimental plot and microhabitat type using the known level of Lake Tahoe on that day (from the USGS) as a reference point. The assumption behind this methodology is that the water table is at the level of Lake Tahoe and, therefore, the height of a plot above the lake is equivalent to the depth to the water table. For the design of the experimental reintroduction we define TYC microhabitats as in Table 1.

In the design of the experimental reintroduction, plants were installed in rows running parallel to the lake beginning 0.5 m to 1m from the water's edge. "Moist shoreline" microhabitat occurred from 6,224.6 – 6,225.7 feet LTD in plots adjacent to the lake, generally in rows 1-5. This, of course, was an arbitrary location, based entirely on lake level the day of planting in late May 2004. At that time the moist shoreline was characterized by saturated soil conditions, wave impacts and inundation for most of the season.

Table 1. Microhabitat elevations and plot locations at six TYC outplanting sites.

Microhabitat	Elevation (feet LTD)	Plot Location
moist shoreline	6,224.6 – 6,225.7	In plots adjacent to the lake at all sites, generally in rows 1-5. At Nevada Beach, in rows 1-5 adjacent to Burke Creek
berm 1(formed in May)	6,225.3	UTE, blocks 1-5
berm 2 (formed in July)	6,224.7	UTE, blocks 1-6
low beach	6,225.8 – 6,227.9	Sand Harbor, rows 15 and less
		Avalanche, all
		UTE, blocks 1-5
		NV, blocks 1-3 and rows 6-8 in blocks 4-9
		Zephyr Cove, plot 1 (planted in2003)
		Taylor, plot 2
dune trough (= back beach depression)	6,224.6 – 6,226	Taylor, in back beach plot 3 rows 1-12 and all of plot 4
high beach	6,228 – 6,230.6	Taylor, plot 2A and plot 3 rows 13 and above
		UTE, blocks 1-5 planted in May, and blocks 1-6 planted in July
		NV, blocks 10-12
		Zephyr Cove, plot 2 (planted in2003)
		Sand Harbor, plot 1 rows 16-20
meadow	>6,230.0	Taylor plot 5

The CS designated the lowest elevation microhabitat as “low beach”, defining it as available only in years with very low lake levels (e.g. below 6,224 ft). However, the moist shoreline fits this definition most closely and we have designated low beach habitat as that occurring between the moist shoreline and high beach in the range from 6,225.8 – 6,228 feet. The maximum lake level in most years is approximately 6,228 ft so low beach is susceptible to inundation while high beach habitat, above 6,228 ft, is almost never inundated and provides a refuge in times of high water.

The berm microhabitat only forms at UTE where wave run-up deposits benches of sand adjacent to the shoreline. The highest surfaces are generally protected from wave impact and inundation, but can still be very moist and close to the water table. The first berm that appeared near the west end of the site, measuring 6,225.3 ft, was about one foot higher than the highest lake level of the season (6,224.3 ft). After the outplanting in May, a second berm formed closer to the lake in the same general location but about a half a foot lower (6,224.7 ft) than the first berm (see Photo 3).

Finally, two other microhabitats, including dune trough (i.e. back beach depression) and meadow, were only present at Taylor Creek. Inland from the high beach and dune a deep, persistent lagoon supporting water lilies (*Nuphar sp.*) and other aquatic vegetation has been apparent over the last several years. Plants were installed in the moist sand on either side of the trough in Plots 3 and 4 within a range of 6,224.5 – to 6,227.5 ft (Photo 6). Beyond the dune trough, 40 plants were installed in the meadow microhabitat within stabilized, perennial vegetation (*Carex*, *Juncus*) (Plot 5 at 6,230 ft).

2.4. Installation of 2004 Experimental Reintroduction and Pilot Replication

A total of 2,454 TYC founders were outplanted at four sites during the last week of May and first week of June 2004 (Table 2). Another 360 were outplanted at UTE in July, bringing the total number of 2004 TYC founders to 2,814 individuals. These were in addition to the 1,424 founders used during the 2003 pilot study (total for both years = 4,238 plants).

Table 2. The number of TYC founders outplanted at sites in 2003 and 2004 (NO=not outplanted).

	Sand Harbor	**Taylor Creek**	**Nevada Beach**	**UTE**	**Zephyr Spit**	*Avalanche*
2003 Pilot (1,424 plants)	297	540	NO	NO	286	*300*
2004 Exper+Pilot (2,814 plants)	*281*	*546*	*582*	*1,045 + 360*	*NO*	*NO*

2.4.1. At 2004 Experimental Reintroduction Sites

Fully replicated, experimental designs were installed at Upper Truckee East and Nevada beaches. The 2004 experimental design for both sites is discussed below. Site maps are found in Appendix A.

2.4.1.1. Upper Truckee East

Four microhabitats were present at UTE; moist shoreline, berm, low beach, and high beach. Founders were installed in blocks of 50, replicated five times for a total of 250 plants per microhabitat. In each block, founders were placed one meter apart in 10 columns with one half meter between each of the 5 rows (see Photo 5). Each founder was marked with a color-coded wooden stake signifying its source population. Plants from 6 seed sources were used at the site. The moist shoreline contained only plants derived from the UTE source; the berm and low beach microhabitats had plants from UTE, Taylor Creek, and Blackwood; the high beach plants were from Lighthouse beach, Regan Al Tahoe, Tallac, Taylor Creek, and UTE. In addition, 45 two year-old founders from various seed sources were outplanted in the low and high beach microhabitats (for age structuring). Outplanting took place on June 3, 2004.

A second berm of pure sand formed in July at the east end of UTE about 15 meters west of first berm. A second outplanting with founders from the UTE and Blackwood source took place on July 29, 2004. Six blocks of 30 founders each (10 columns by 3 rows) were installed on the new berm and in the high beach for a total of 180 plants per microhabitat. This additional planting brought the total number of founders outplanted at UTE to 1,405.

2.4.1.2. Nevada Beach

A total of 582 founders were outplanted within the temporary fencing around Burke Creek at Nevada Beach on May 27, 2004. Plants were from the Taylor Creek, Cascade, and Tahoe Meadows sources. Three blocks, containing 48 founders each (3 columns by 16 rows), were installed on the north side of Burke Creek in low beach habitat (Photo 7). Six blocks of 48 founders each (6 columns by 8 rows) were placed on the bank of the creek with three blocks on the north side and three on the south. Rows 1-5 were in moist shoreline microhabitat and the upper three rows (6-8) were considered low beach (Photo

8). The beach on the south side of the creek was on significantly higher ground than the north side so three blocks of 50 plants each (10 columns by 5 rows) were installed in high beach habitat. Overall, 180 founders were outplanted in moist shoreline, 252 in low beach, and 150 in high beach microhabitats.

2.4.2. At the 2003 Pilot Project Sites

A new cohort of founders ("one year-olds") was outplanted in and among the 2003 pilot project founders ("two year-olds') at two sites in 2004; Taylor Creek and Sand Harbor. These installations were meant to test the ideas of age-structure outplanting and founder–cost averaging (see Introduction). The 2004 replication of the pilot project design for both sites is discussed below. Site maps are in Appendix A.

2.4.2.1. Taylor Creek

A total of 541 founders were outplanted in two enclosures at Taylor Creek on May 19, 2003. Founders were divided into 5 plots, each representing at least one microhabitat. Plots 1 and 2, containing a total of 180 plants, were installed in the moist shoreline and low beach, respectively, near the mouth of Taylor Creek and enclosed with temporary snow fencing. In 2003, the creek inundated both plots, building up a berm along the moist shoreline and creating a natural beach trough in Plot 2. Taylor Creek flowed sharply to the west in 2004 causing failure of the permanent enclosure and eroding all of Plot 1. New temporary snow fencing was erected in May and the 2004 cohort was outplanted on May 25, 2004. A new Plot 1, containing 45 founders was outplanted in the moist shoreline microhabitat adjacent to Lake Tahoe. Naturally occurring TYC were again present in Plot 2 and immediately outside the enclosure to the west. A cohort of 240 founders were outplanted in transects between the columns of the persisting 2003 founders of Plot 2. Therefore, Plot 2 contained a total of 480 plants in low beach habitat (240 planted in 2003 and 240 planted in 2004). An additional plot of 60 founders (Plot 2A) was established above Plot 2 at 6,228.5 feet in high beach microhabitat.

Within the permanent enclosure the persistent dune trough lagoon again extended all the way down the beach toward the parking lot. Plots 3 and 4 were situated around the margins of this trough and new cohorts of 100 founders each were outplanted in the columns between the persisting 2003 cohort of both plots (see Photo 6). In order to measure the elevation of this microhabitat, we assumed the trough represented the exposed water table with a level equivalent to that of Lake Tahoe. Using this method, dune trough micro habitat occurred in the range of 6,224.6-6,226.0 feet. Although this range is similar to that low beach, plants in the trough are well-protected from wave impact and inundation and would presumably be present even in high water years. Plants occupying dune trough microhabitat occurred in rows 1-12 in Plot 3 and all of Plot 4. Rows 13 and above in Plot 3 were at an elevation of 6,228.0-6,229.2 feet and were considered high beach microhabitat.

Although all founders in meadow Plot 5 died by July in 2003, 40 plants were again outplanted in 2004 behind the lagoon in the same stabilized vegetation at approximately 6,230 feet. In all plots, the color-coded wire flags marking plants in the 2003 cohort were replaced with plain wooden stakes. The 2004 cohort was marked with color-coded wooden stakes that signified the seed source.

2.4.2.2. Sand Harbor

A total of 297 founders were outplanted on May 20, 2003 on the north end of the beach near the boat ramps. This site is very rocky, so it was necessary to work around boulders and divide the plants into 3 plots. In 2003, all of Plot 3 was inundated so it was not monitored or re-planted in 2004. On May 24, 2004 Plots 1 and 2 were both outplanted with 281 founders in the columns between the 2003 cohort; 141 founders were outplanted in Plot 1 and 140 in Plot 2. The 2004 founders were marked with color coded wooden stakes signifying the seed source and the 2003 cohort was marked with plain stakes. The Nevada Division of State Parks installed a permanent fence that expanded the size of the 2003 enclosure by 5m to the south, fully enclosing the outplanting.

2.5 Monitoring

2.5.1 2004 Experimental Reintroduction

Demographic, physiological, and disturbance monitoring techniques developed for the 2003 pilot project were improved and applied to the 2004 experimental reintroduction. As such, this is “cause and effect” monitoring and is used to test management hypotheses and answer KMQs. Detailed protocols are available in Appendix B of the previous report in this series (Pavlik and Stanton, 2003). A new datasheet (Appendix B of this report) was developed to record the fate of every founder, allowing subsequent calculations of mortality rates, survivorship to reproduction, and estimates of reproductive output using models previously developed (Pavlik et al 2002b). The water relations monitoring (Pavlik 1987, 2001), measured physiological stress levels (i.e. xylem water potentials) of founders at different microtopographic positions with respect to lake level.

2.5.1.1. Demographic Monitoring

Three of the agency landowners (USFS, CTC, and NDSP) committed personnel for outplanting and monitoring efforts throughout the 2004 growing season. BMP trained monitoring crews individually at each site on the first scheduled monitoring day, two weeks after planting. Reintroduced populations were evaluated at 2 weeks and 4 weeks after outplanting and thereafter on a monthly basis through October. Data collection parameters included: founder position, seed source**,** phenology**,** vigor**,** initial and final size**,** and current status. Initial plant size was measured during the 2-week monitoring and again in September at the time of peak reproductive activity.

Sexual reproductive output was estimated based on an equation that links canopy size (area) to seed output by individual plants ($y=3.609x - 109.542$, $r = 0.81$, where y is the number of seeds per individual and x is canopy area in square centimeters) (see Figure 4 in Pavlik, Stanton, and Childs, 2002). Asexual reproductive output (cloning) was estimated from counts of plantlets that appeared within a few centimeters of the original founder. We often confirmed attachment of plantlets to founders by digging around the base of the founder to uncover the lateral underground roots that give rise to plantlets. Plantlets could develop into physiologically independent ramets (“stems” in the CS) from vegetative growth of a single genetic individual (genet).

2.5.1.2. Physiological Monitoring

Monitoring of plant water status was conducted twice during the 2004 growing season; once in July, and again in late September during the period of maximum reproduction. An attempt was made to cluster the monitoring days and obtain the measurements under seasonally "typical" conditions: clear, sunny, warm, and not within 5 days after a storm front has 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 (Photo 9). 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.

2.5.1.3 Disturbance Monitoring

Disturbance monitoring was conducted in conjunction with the demographic monitoring. An additional disturbance data set was obtained on July 5th in an attempt to document any impacts from heavy beach use on the 4th of July weekend. At five times throughout the season, the monitoring 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 TYC plants or the fence and signs. Photographs were taken of any significant disturbances and maps were generated to mark the areas of disturbance. Plot aisles and perimeters were raked smooth after all monitoring to obliterate any signs of the most recent disturbance and to discourage people from entering the plots.

2.5.2. Monitoring the Pilot Project 2003 Cohort

Two of the 2003 pilot project sites were not outplanted with additional founders in 2004: Avalanche beach and Zephyr Spit. The 2003 outplanting design for both sites is discussed below. Site maps are in Appendix A. of the previous report (Pavlik and Stanton 2004).

2.5.2.1. Avalanche

A total of 300 founders had been outplanted at Avalanche on June 3, 2003. Plants were arranged in 2 plots, and the colored wire flagging that marked each plant was still present in 2004. Plot 1 originally contained 240 founders in 10 transects that extended out over a 12 m elevational rise above the waterline. For analysis in 2004, the moist shoreline microhabitat was redefined to include rows 1-14, instead of just rows 1-5, while the remaining 10 rows were classified as low beach. All 60 plants in Plot 2 were included in low beach microhabitat. Naturally occurring TYC plants found in 2003 above Plot 2 (among boulders) and below (within a depression of beach wrack) persisted through 2004 but were not monitored. No fences were installed at this site because of the relatively remote location and the protection provided by downed logs from the 1956 avalanche. Signposts at the water's edge and on the western side of the plots indicated that the beach was closed for restoration.

2.5.2.2. Zephyr Spit

A total of 286 founders had been outplanted on May 22, 2003. Plot 1, enclosed with temporary snow fencing, contained 60 founders in the moist shoreline microhabitat within rows 1-5. Rows 6-12 were considered low beach. Plot 2 abutted upland vegetation (bitterbrush/pine) and was permanently fenced with wood posts and wire. It contained 130 founders in high beach microhabitat. The wire flagging installed in 2003 was replaced with wooden stakes marking the location of each plant.

2.6 Precision Seeding Experiment

A precision seeding experiment was installed at Upper Truckee East at the time of the June 2004 outplanting. Plywood sowing frames (1.25 X 1.25 m) with 100 hole grids (10 X 10) were used as guides for precisely locating seeds in four microhabitats; low beach, high beach, berm, and moist shoreline. A frame (one replicate) was placed on the ground and a one foot piece of rebar was inserted in each of three small holes (two at the top and one at the bottom) on each frame. The rebar was then driven into the ground and left in place so the frame could be removed and returned to the exact same location for subsequent monitoring. Next, a small number (3-10 seeds) of clean TYC seeds were placed on the beach sand surface in each sowing hole and lightly covered with sand taken from just outside the frame. Three frames were sown in each microhabitat for a total of 300 sown holes per microhabitat. To avoid any displacement of sown seeds, and to test for more natural patterns of germination, plots were not watered. Plots were monitored one month after sowing.

3.0 Results

3.1 Nursery Propagation of Founders

Sierra Valley Farms delivered 1,742 founders in supercells and 50 two year-old plants in D-pots to the USFS Washoe Valley nursery in May 2004. Washoe produced 872 supercells initially and was required to split out over 600 cells only three weeks before outplanting, to produce a total of 1,566 founders. The nursery at Washoe kept approximately 300 plants to age for subsequent age-structured experimental plantings. In May, a combined total of 3,308 founders were available for outplanting (Table 3).

Table 3. Number of nursery propagated TYC founders available in May 2004 from nine source populations.

Seed Source Populations	Number of TYC Founders
Blackwood North and South (BS/BN)	547
Cascade (CD)	247
Cave Rock (not used)	109
Regan Al Tahoe (RA)	245
Lighthouse (LT)	241
Tallac (TL)	294
Taylor Creek (TY)	706
Tahoe Meadows (TM)	269
Upper Truckee East (UTE)	650
Total for 2004	**3,308**

After delivery founders were sorted at the Washoe Valley nursery according to seed source and then assigned a vigor code (low, medium, and high) and a phenological state code (vegetative, flowering, fruiting, and senescent). The vigor code was based on rather a plant looked healthy and partially reflected different planting dates. Sierra Valley Farm planted earlier than Washoe and kept the plants in the greenhouse longer. By May, most of the plants from Washoe were small and vegetative, while plants from Sierra Valley Farm had gone to fruit in the greenhouse and many had already begun to senesce.

Overall, 48% of founders were coded as low vigor and 52% as high vigor (some plants in the July planting at UTE were classified as medium, but otherwise it was not used as a vigor category). Low vigor plants in the 2004 cohort of founders were not divided equally among the four outplanting sites ranging from 24% of the founders at Taylor to 48% of the founders at UTE (Figure 2).

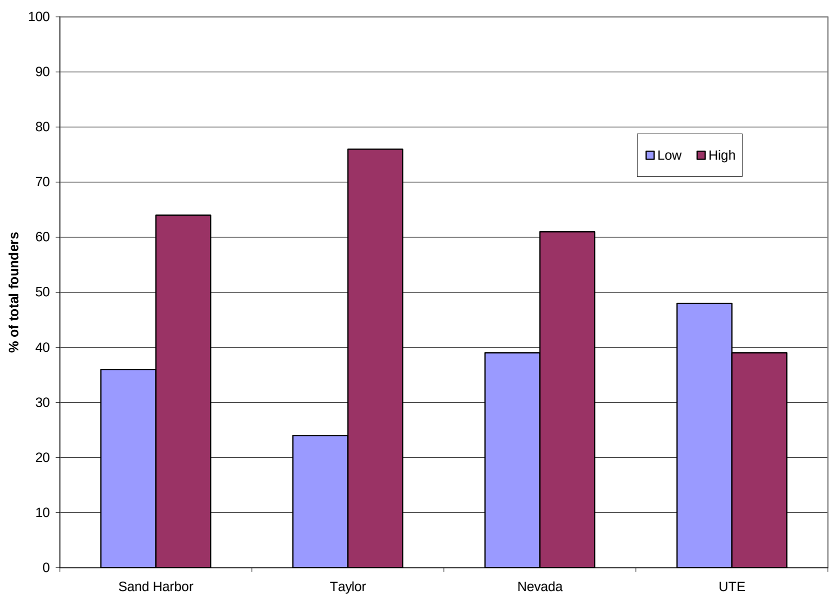


Figure 2. The vigor of 2004 founders at all reintroduction sites at the time of outplanting, May 2004. Plants at UTE coded as medium vigor were not included so the sum of its columns does not equal 100%).

The eight different seed sources also varied with respect to initial vigor. Founders from the Lighthouse, Regan Al Tahoe, Tallac, and Taylor Creek sources were mostly high vigor, while a majority of the founders from Cascade, Tahoe Meadows, Blackwood, and Upper Truckee were low vigor (data not shown). However, this was likely due to variations in phenology that resulted from different planting times and growing conditions at the two nursery facilities. Plants from Washoe that were split apart into more cells three weeks prior to planting were generally of low vigor because they were smaller and less well-established. In contrast, many of the plants from Sierra Valley Farms had fruited more than one time and were beginning to senesce.

Overall, the quality of plants in the 2004 cohort was much lower than in the 2003 pilot project. In that year, only 14% of plants were low vigor, while the rest were divided nearly equally into medium and high vigor (43 and 42%, respectively). The lower quality of the 2004 plants was due to disparate nursery practices and both nurseries fell short of producing the requested number of seedlings. Although nursery practices influenced initial vigor, the plants became mixed up in the sorting process and it was not possible to track or monitor founder nursery source.

3.2 Demography of the 2004 Experimental Reintroduction

3.2.1. Nevada Beach

Overall Performance: Over 75% of the 582 founders at Nevada Beach survived to September 2004 (439 individuals). Of these, 75% were reproductive in September, producing an estimated 133,992 seeds. Mean seed output was high (498 seeds per plant) and reproductive individuals were fairly large (mean canopy area = 151 cm^2). The site is only a few miles south of Zephyr Spit and these values are similar to those documented there in 2003 (mean seed output = 532 seeds per plant and mean canopy area = 172 cm^2). The higher first year survivorship at Nevada (75%) compared to Zephyr Spit (58%), is likely due to the fact that plants in the moist shoreline microhabitat at Nevada Beach were installed along the shore of Burke Creek instead of Lake Tahoe and, therefore, did not experience the strong wave impacts or prolonged inundation that occurred during the first year at Zephyr Spit.

Effect of Microhabitat:: Three microhabitats were present at Nevada Beach; moist shoreline, low beach, and high beach. The moist shoreline (6,224.6-6,225.7) was located along the shore of Burke Creek to resemble moist hydrological conditions along the immediate shore of Lake Tahoe. From very early in the season survivorship of founders in the moist shoreline and low beach (84 and 79%, respectively) were significantly higher than the high beach (50%)(Figure 3). Further analysis, however, revealed that this difference was primarily due to microtopographic differences with respect to the two sides of the creek. Plants on the north side of Burke Creek were at a slightly lower elevation with respect to the water table compared to plants on the steeper and higher south side. North side plants had significantly higher survivorship (93%) than those on the south side (58%) presumably because roots had better access to the water supply (Figure 4).

The proportion of surviving founders that became reproductive was also significantly different between the microhabitats (Figure 5). More individuals reproduced in the moist shoreline in September than the other two microhabitats, although by October a significant difference between low beach and high beach also developed. Mean survivorship to reproduction (the proportion of reproductive individuals of the total number of founders) essentially followed the same pattern, but the relationship was not as strong (Table 4).

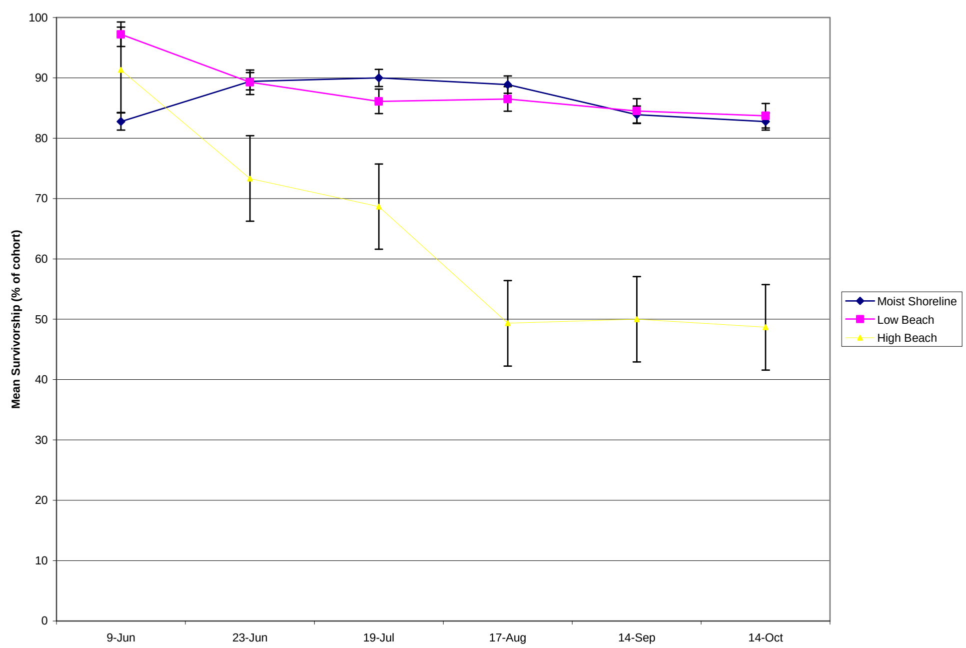


Figure 3. Mean survivorship of 2004 TYC founders in three microhabitats at Nevada Beach, 2004. Differences between high beach and the other two microhabitats was significantly different (ANOVA $p<0.01$) after June 9.

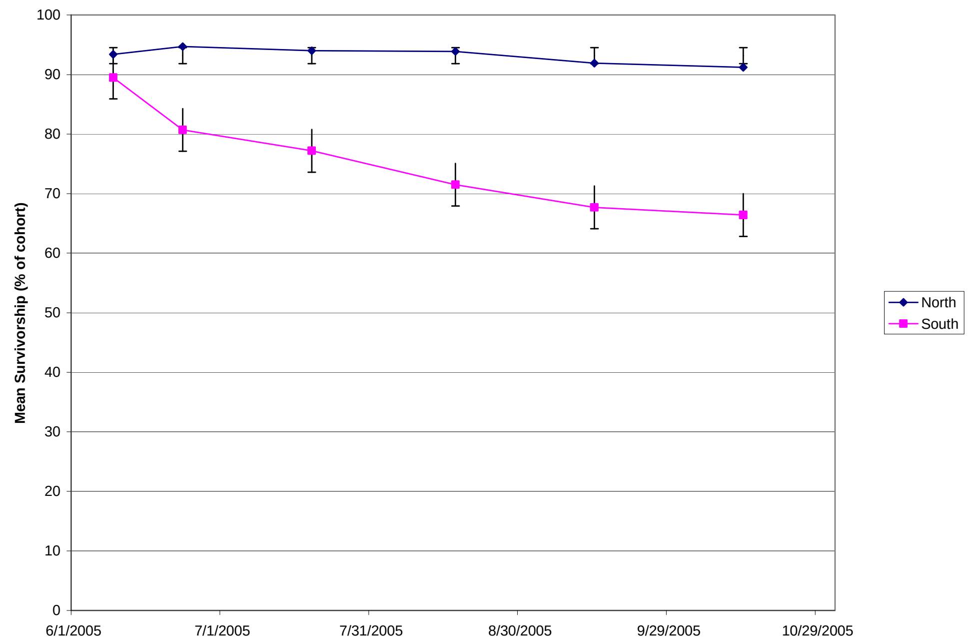


Figure 4. Mean survivorship of 2004 TYC founders on two slope aspects (north or south side of Burke Creek) at Nevada Beach, 2004. Differences between aspects is significantly different (ANOVA p<0.0002) after June.

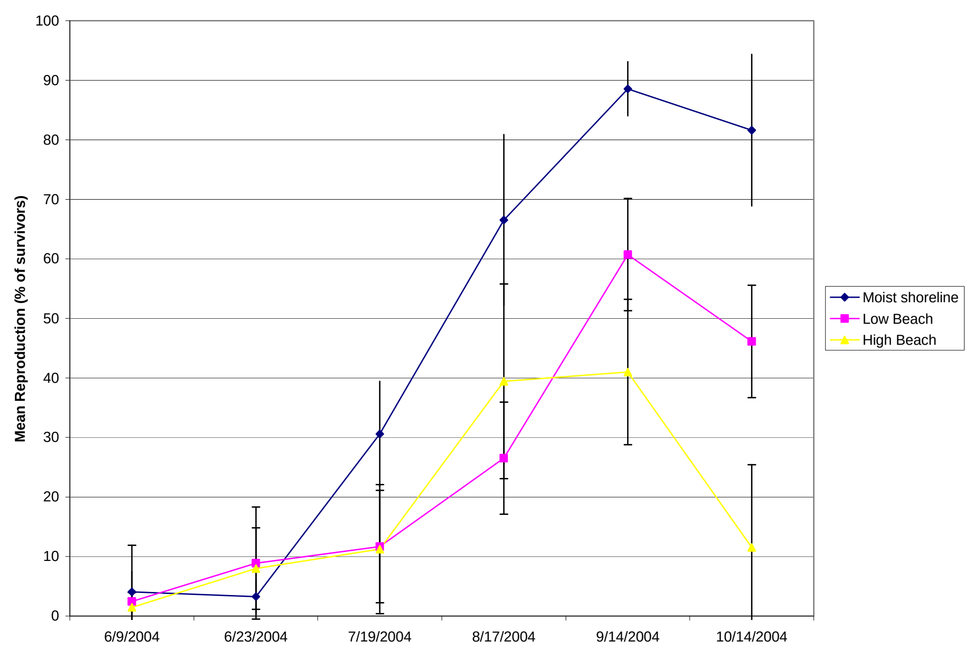


Figure 5. Mean reproduction of the 2004 TYC founders, expressed as the proportion of surviving individuals in fruit, in three microhabitats at Nevada Beach, 2004.

Founders in the high beach were significantly smaller and output less seed than founders in the moist shoreline or low beach (Table 4). While plant size and reproductive capacity were similar in the moist shoreline and low beach, plantlet production (# plantlets per microhabitat) was only high in the moist shoreline. This suggests that plants in the high beach experienced levels of water stress that essentially shut down both seed and plantlet output while those in the low beach were able to set seed but lacked sufficient resources to make plantlets.

Table 4. Mean survivorship to reproduction, mean canopy area, mean seed output (#/founder), total seed production (#/microhabitat) and total plantlet production (#/microhabitat) in three microhabitats at Nevada Beach in September, 2004. 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	74a	167a	510a	69.780	209
Low beach	50ab	153a	527a	63,721	17
High beach	21b	22b	61b	492	10

3.2.2. Upper Truckee East

Overall Performance: Survivorship of the June 2004 outplanting of 1000 founders was 73% in September 2004. The late July planting fared almost as well, with 252, or 70% of that cohort surviving to September. Surprisingly, only 51% (23 individuals) of the two year-old founders survived to September bringing the total number of surviving TYC founders in all plots to 1009, or 72% of the total outing planting at UTE in 2004.

Effect of Microhabitat:: Four microhabitats were present at UTE: moist shoreline, berm, low beach, and high beach. The first outplanting occurred in early June 2004 and significant differences in survivorship were apparent by late July (Figure 6). By September, survivorship in the moist shoreline and berm habitats, 93 and 97% respectively, was significantly greater than the low or high beach. Survivorship in the high beach (66%) was also significantly greater than the low beach (38%). The low beach experienced large declines in survivorship as the season progressed and the cover of lupine (*Lupinus lepidus*) increased (see Photo 4). Individual TYC plants that survived in the low beach plots were thin, fragile, and often etiolated as they grew out of the lupine shade and towards the sunlight (Photo 10). Mean lupine cover in all 11 of the high beach plots (on both planting dates) was only 3.5%, but in the five low beach plots it was 59%, a significant difference (ANOVA $p<0.0001$). Lupines were absent from the berm and moist shoreline plots. Vegetation cover in the berm plots was almost exclusively TYC with small contributions from *R. curvisiliqua* and cinquefoil (*Potentilla*). In the moist shoreline plots mean vegetation cover was 29%, lower than that of the low beach but significantly higher than found in the high beach (ANOVA $p<0.0001$).

The effects of vegetation cover within microhabitats may have been evident in founder size and reproductive output. Reproduction was most successful in the berm plots where total seed and plantlet production were much higher than in other microhabitats (Table 5). Nearly all (93%) of the surviving founders in the berm plots fruited in September and these were significantly larger and output more seed (480 seeds/founder) than those from other microhabitats. Interestingly, mean seed output in the low beach (250 seeds/founder) was not significantly lower compared to founders on the berm, probably because the small number of individuals that did reproduce occurred between gaps in the lupine canopy where they received sufficient light to grow large and set seed. Despite differences in vegetation cover, surviving founders in the moist shoreline and berm in both August and September were significantly more likely to reproduce than founders in low or high beach plots (Figure 7). Mean survivorship to reproduction (of the total number of founders, not just survivors) followed a similar pattern, suggesting that ensuring reproductive success in drier habitats requires a greater investment of founders (Table 5).

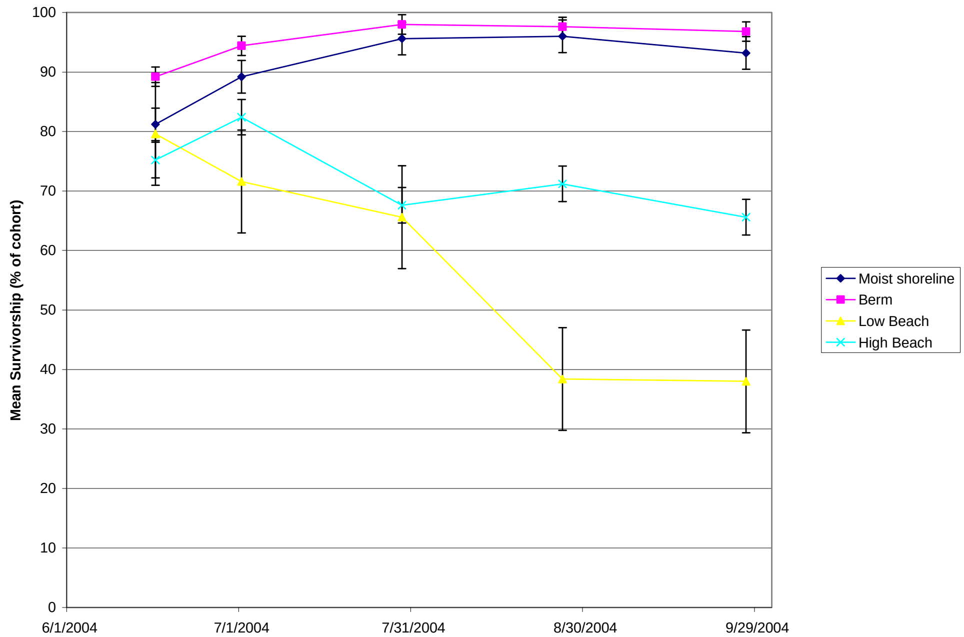


Figure 6. Mean survivorship of 2004 TYC founders in four microhabitats at Upper Truckee East, 2004. Differences between moisture shoreline and berm and the other two microhabitats was significantly different (ANOVA p<0.05) after July.

Table 5. Mean survivorship to reproduction, mean canopy area, mean seed output (#/founder), total seed production (#/microhabitat) and total plantlet production (#/microhabitat) in three microhabitats at Upper Truckee East in September 2004. Mean values in a column followed by different letters are significantly different (ANOVA p<0.0001).

Microhabitat	Mean Survivorship to Reproduction (%)	Mean Canopy Area (cm2)	Mean Seed Output (#/founder)	Total Seed Production (# /microhabitat)	Total Plantlet Production (#/microhabitat)
Moist shoreline	77a	24b	52b	2,734	0
Berm	90a	127a	480a	82,992	374
Low beach	6b	51b	250ab	3,747	0
High beach	14b	31b	182b	3,275	11

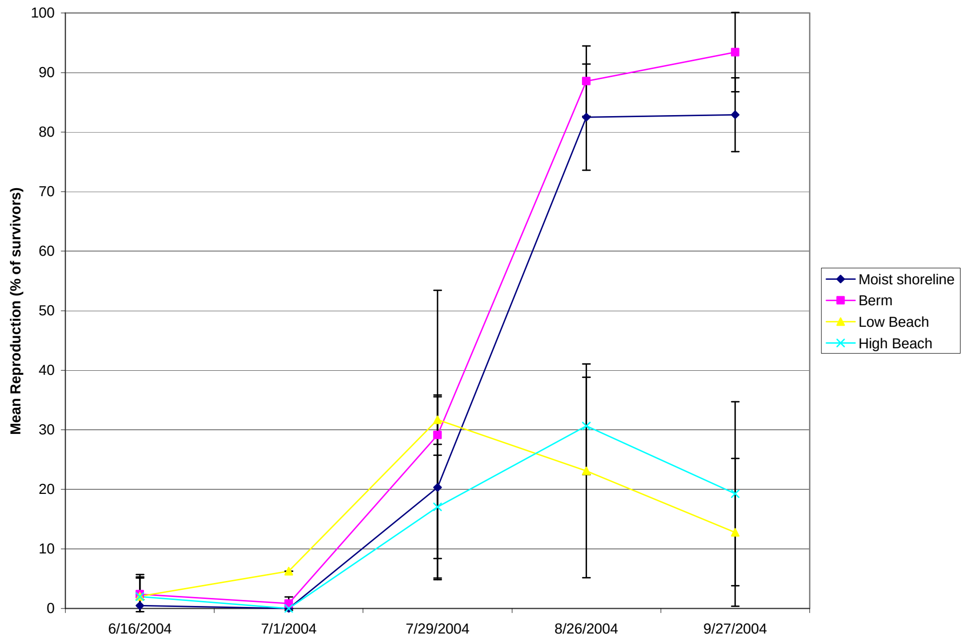


Figure 7. Mean reproduction of the 2004 TYC founders, expressed as the proportion of surviving individuals in fruit, in three microhabitats at Upper Truckee East, 2004.

<u>Effect of Outplanting Time:</u> Overall survivorship of the late July outplanting in September was 70%, almost equal to the 73% of the June outplanting. However, there was a marked effect of microhabitat. In the high beach, founders outplanted in late July had decreased survivorship in September and October compared to those planted in June (Figure 8). The few plants that managed to survive from the July cohort in the high beach did not output any seed or plantlets, whereas the June cohort produced an estimated total of 3,275 seed (Table 6). In the berm, mean canopy size and seed output was not significantly different between the June and July cohorts, but the July cohort was significantly less likely to reproduce and therefore total seed and plantlet production was dramatically reduced with the later planting date (Table 6).

The later outplanting time did not change the overall pattern of survivorship and reproduction between the microhabitats and the berm remained far superior habitat to the high beach. Founders in the berm plots had significantly higher mean survivorship over the entire season than founders in the high beach. Founders in the berm were also significantly more likely to reproduce (Figure 9), plant canopy and seed output per plant were also significantly greater, and therefore total seed and plantlet production were much higher (Table 6) than the high beach

These data strongly suggest that it is optimal to outplant earlier in the growing season. Late planting strongly limits growth and reproduction in both mesic and xeric microhabitats. Early outplanting is especially required for sub-optimal microhabitats to ensure any reproduction at all.

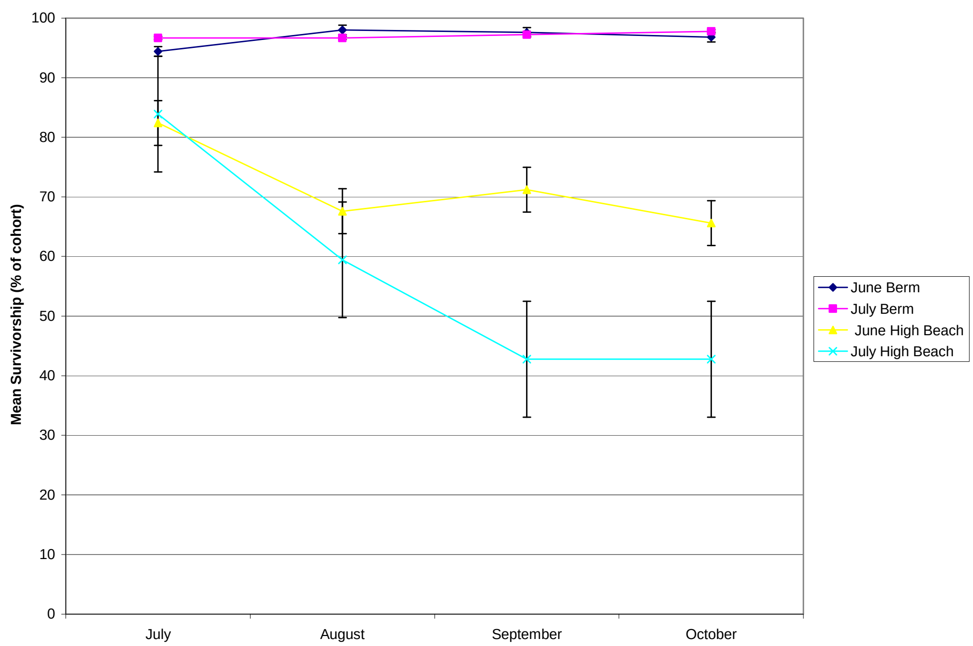


Figure 8. Mean survivorship of 2004 TYC founders in two microhabitats planted in early June or late July 2004 at Upper Truckee East. Differences between berm and high beach became significant (ANOVA $p<0.0001$) after August.

Table 6. The effect of outplanting time (June or July) on mean reproduction, mean canopy area, mean seed output (#/founder), total seed production (#/microhabitat) and total plantlet production (#/microhabitat) in three microhabitats at Upper Truckee East in September 2004. Mean values in a column followed by different letters are significantly different (ANOVA p<0.001).

Microhabitat/Date	Mean Reproduction (% of survivors)	Mean Canopy Area (cm2)	Mean Seed Output (#/founder)	Total Seed Production (# /habitat)	Total Plantlet Production (#/habitat)
Berm / July	40b	140a	436a	32,265	152
Berm /June	93a	127a	480a	82,992	374
High beach/ July	4c	8b	0	0	0
High beach/June	19c	31b	182b	3,275	11

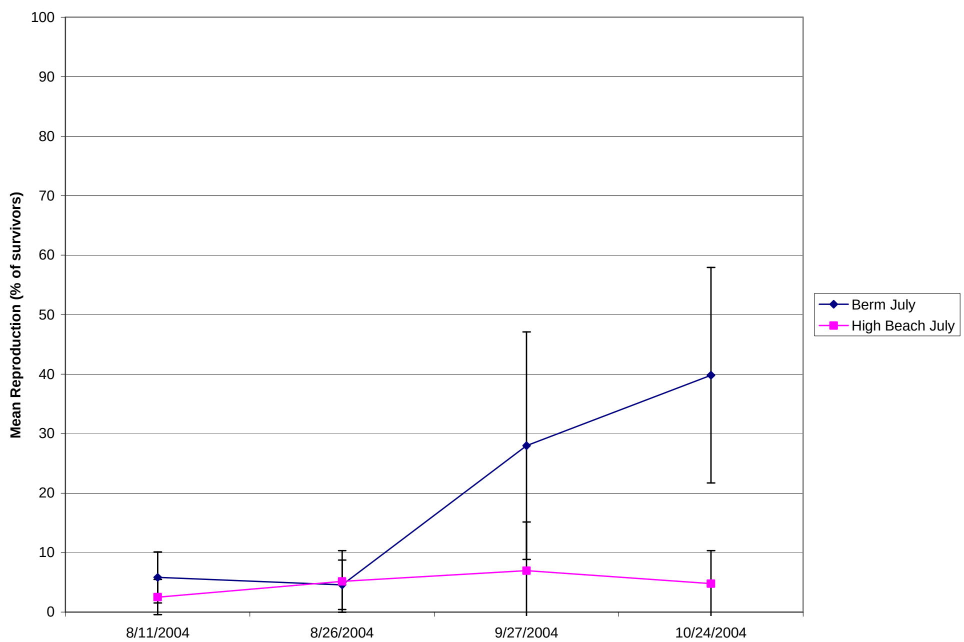


Figure 9. Mean reproduction of the July 2004 TYC founders in two microhabitats at Upper Truckee East. Differences between berm and high beach became significant (ANOVA p<0.03) after September.

3.3 Effects of Initial Founder Vigor

Survivorship: At the time of outplanting in June 2004, 48% of plants were coded as low vigor and 52% were high vigor. In contrast, only 14% of plants in the 2003 pilot project cohort were low vigor. The large number of low vigor plants in the 2004 cohort was not divided equally among the four outplanting sites, as previously shown (Figure 2). In addition, the eight different seed sources varied with respect to initial vigor, although this was mainly attributed to different planting times and protocols used by the two nurseries. An attempt had been made to randomly distribute low vigor plants among all plots within a site.

Initial vigor in 2004 did not appear to influence survivorship or reproduction at either Taylor Creek or Sand Harbor (unlike the results in 2003). Survivorship of low and high vigor founders was virtually identical at Sand Harbor (survival= 43% of low vigor and 44% of high vigor) and only slightly different at Taylor Creek (survival= 61% of low vigor and 76% high vigor).

At Upper Truckee East, three codes levels (L, M, H) were used to describe initial vigor of founders. Overall, 66% of low vigor founders survived to September and 55% of those reproduced, while 77% of high vigor founders survived to September and 53% of those reproduced. While overall survivorship was fairly similar, the influence of initial vigor did vary among microhabitats. Unexpectedly, initial vigor made the largest difference in optimal microhabitats (moist shoreline and berm) where low vigor founders had significantly lower survivorship (Table 7). In optimal habitats with plentiful resources (i.e. soil moisture) we thought the effect of initial vigor would be expected to be minimal because ample water would enable low vigor plants to re-establish. The significant results are likely due to the very small variability in the data because survivorship of all founders in those habitats was close to 100 percent.

Table 7. The influence of initial vigor on mean percent survivorship (n = 5 blocks) in the TYC June 2004 cohort in four microhabitats at Upper Truckee East, September 2004. Values in a column followed by different letters are significantly different (ANOVA p<0.001).

Initial Vigor Code	Berm	Moist Shoreline	Low Beach	High Beach
Low	86.7b	92.5b	40.6a	61.9a
Medium	98.5a	98.7a	35.7a	59.9a
High	100a	100a	486a	69.1a

At Nevada Beach, overall mean survivorship of low vigor (72%) and high vigor (79%) founders in September was not significantly different. However, the effects of initial vigor were not apparent in either optimal or sub-optimal habitat. At Nevada Beach the main microhabitat feature that influenced survival rates was slope aspect of the creek channel. The south side of Burke Creek was much higher above the Lake and had significantly lower survivorship than the North side, as previously shown (Figure 4). At the two week monitoring period in June, the effects of initial vigor were apparent on the south side of the creek, where mean survivorship of high vigor founders was 95% and 72% for those with low vigor. On the north side of the creek, however, survivorship of high and low vigor founders was 97% and 93%, respectively. The vigor difference on the south side had disappeared by September. Mean survivorship of low vigor founders (66%) was not significantly different than high vigor individuals (56%) and, therefore, initial vigor does not appear to be the cause of lower survivorship on the south side of the creek. Survivorship remained high on the north side of the creek and, unlike at Upper Truckee East, initial vigor did not significantly affect survivorship in this optimal, mesic habitat (low vigor=95 %, high vigor =92%).

The lack of effect of initial vigor on survivorship contrasts sharply with the pattern observed in 2003 pilot project. In 2003, founders with high initial vigor were two to three times more likely to survive than those with low initial vigor. While plots were not replicated and no statistical validation is possible, the magnitude of the vigor effect suggests that the 2003 patterns were real. In 2004, the increase in lake level may have increased water availability and effectively eliminated the disadvantage of low vigor founders. A higher water table would increase soil moisture at higher microhabitat elevations, thus reducing water stress and enabling low vigor founders to become established in greater numbers.

Reproduction: Initial vigor did not appear to influence the proportion of survivors that became reproductive at Sand Harbor (35% low vigor and 33% high vigor) or Taylor Creek (53% low vigor and 69% high vigor). In the experimental plots the mean proportion was not significantly different at Nevada Beach between the two sides of Burke Creek (north=low vigor 95% and high vigor 92%, south= low vigor 66% and high vigor 56%) or among founders at Upper Truckee (data not shown). The lack of effect of vigor on reproduction in 2004 contrasts with the 2003 pattern where low vigor founders were more likely to reproduce than high vigor founders. The 2003 results indicated a possible "stress-induced hardiness" had been imparted during nursery propagation. In 2004, the rise in lake elevation would likely have ameliorated such stress.

3.4 Effect of Founder Population Sources

Survivorship: Founders were propagated from seed from 8 core and priority restoration sites: Blackwood, Cascade, Lighthouse, Tallac Creek, Taylor Creek, Regan Al Tahoe, Tahoe Meadows, and Upper Truckee East. Results from the 2003 pilot project indicated that seed source did not affect survivorship. A second year of results from Taylor Creek again indicates that survivorship was similar among founders from four different seed sources (Figure 10). The plots were not replicated, however, so statistical evaluation was not possible.

In the replicated experiments at Nevada Beach and Upper Truckee East, the data clearly establish that seed source does not affect founder survivorship. Mean percent survivorship in September at Nevada Beach was not significantly different between founders from three seed sources in any of the tested microhabitats (Figure 11). Similarly, mean survivorship in the berm and low beach at UTE in September was not significantly different (Figure 12). The pronounced difference in overall survivorship between the two habitats did not influence the effects of seed source. Founders from three other sources were planted in high beach microhabitat at UTE, and mean percent survivorship was also not significantly different (Figure 13).

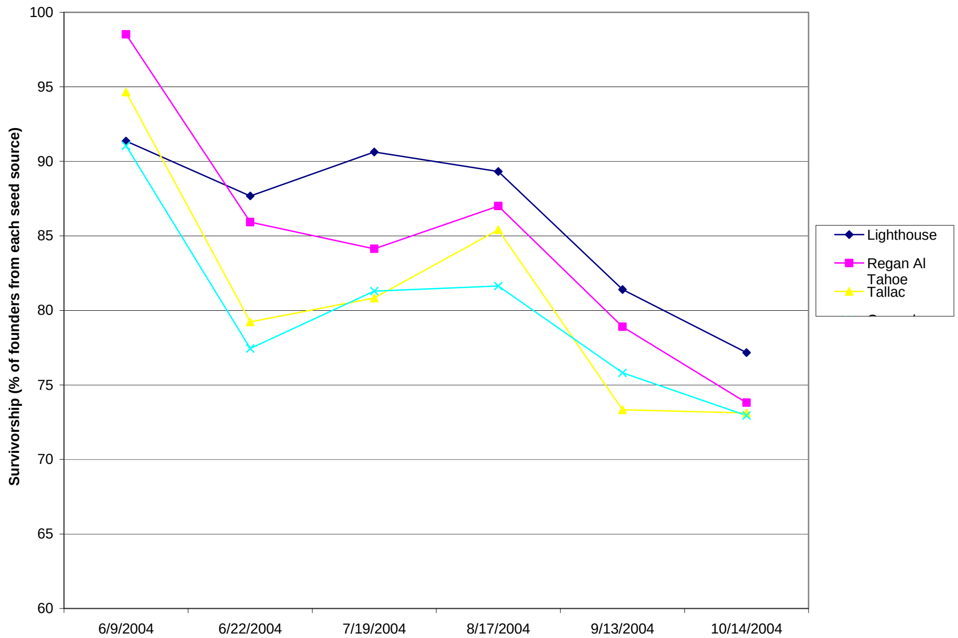


Figure 10. Percent survivorship of TYC founders from four seed sources at Taylor Creek, 2004.

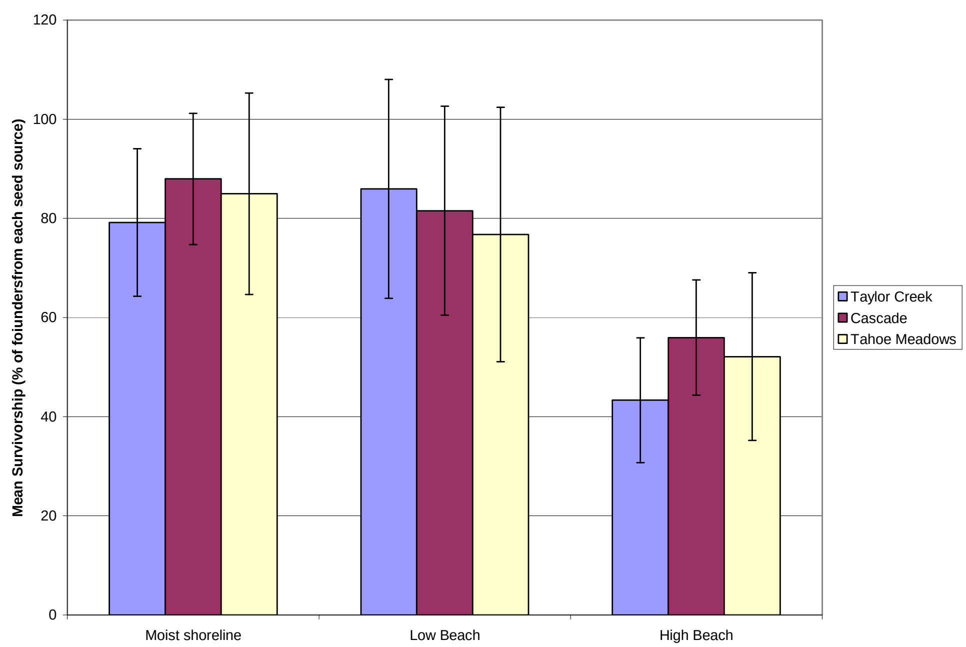


Figure 11. Mean percent survivorship of three seed sources in three microhabitats at Nevada Beach, September 2004. Bars indicate ± 1 SD.

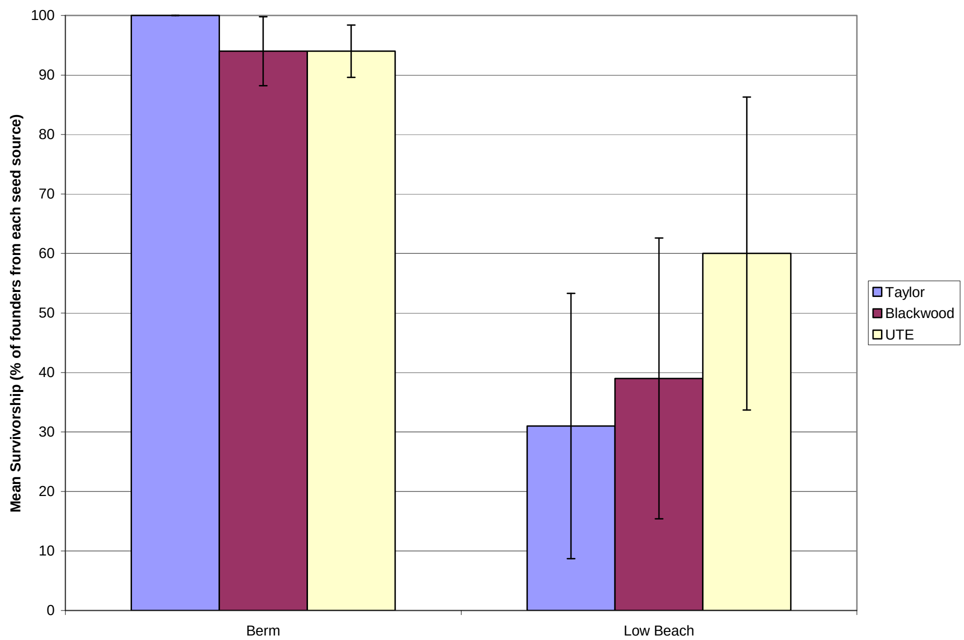


Figure 12. Mean percent survivorship of three seeds sources of the June cohort in berm and low beach microhabitats at UTE, September 2004. Bars indicate ± 1 SD.

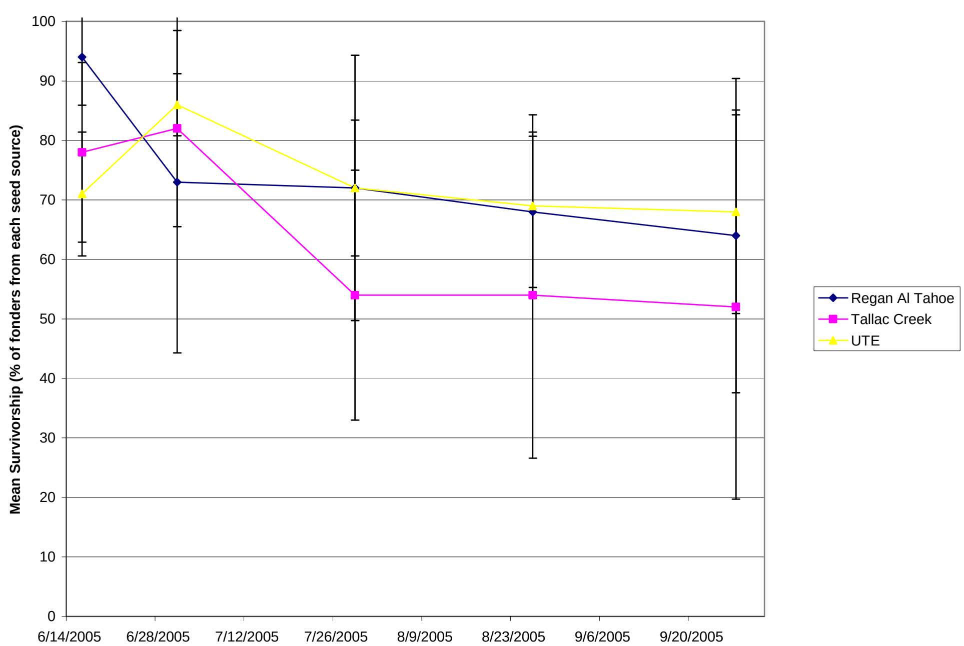


Figure 13. Mean survivorship of three seed sources of the June cohort in the high beach microhabitat at UTE, 2004. Bars indicate ± 1 SD.

These data strongly suggest that founder genotypes (expressed *in situ* as fully functional phenotypes) do not play a significant role in the survival of outplanted seedlings. Therefore, until data to the contrary become available, restoration designs need not incorporate seed source as a variable. In order to retain any unique alleles, that may be present in some source populations (see Hipkins and DeWoody 2004), it would be ideal to mix seed from many locations for propagation purposes, but tracking founder seed source is not necessary.

3.5 Water Status of Founders in 2004

Xylem water potentials of TYC founders were measured to directly evaluate their water status in different microhabitats at different times of the day and season. Xylem water potentials integrate the effects of ambient soil and atmospheric moisture conditions with minimal disturbance to established plants and the habitat itself. Well-hydrated plants have higher water potentials (less negative and closer to 0 bars or 0 MPa (megapascals), 10 bars = 1 MPa) because water is moving through the plant with low tension in the conducting tissues (xylem). As water becomes less available from the soil, plant water potentials decrease (i.e. become more negative) and the plant experiences greater stress (e.g. loss of cellular turgor pressure and high tensions in the xylem). Water potentials for forbs in mesic habitats generally range from at or near 0 bars (0 MPa) for a fully watered plant to a lower threshold of -17 bars (–1.70 MPa) for a dehydrated plant that is stressed and near the wilting point of leaves.

For the pooled data from all sites, early season (July) pre-dawn water potentials were significantly different between all three microhabitats (Table 8). These differences are most likely due to differences in available soil moisture because stomata are closed before sunrise and the sandy substrate is similar between microhabitats. By the afternoon, when the plants were experiencing the greatest levels of water stress, the difference between founder water potentials in the low and high beach had disappeared. This indicates that atmospheric factors (low humidity, higher air or leaf temperatures) had a greater effect than differences related to soil moisture.

The magnitude and pattern of water potentials was only slightly different later in the season (September) when lake levels were lowest and rainfall scarce. Water potentials were significantly lower in the high beach at pre-dawn, again indicating differences in soil moisture. By midday, values in the moist shoreline were significantly greater (Figure 14). Data from the moist shoreline suggest a weak seasonal development of water stress. It may be, however, that higher stress levels occur in August and were simply undetected in 2004.

Table 8. Pre-dawn (AM) and midday (PM) water potentials of TYC in selected microhabitats in July and September, 2004. Data pooled from all sites, values are in bars. Values in a column followed by different letters are significantly different (ANOVA p <0.0001).

Microhabitat	**July**		**September**	
	AM	PM	AM	PM
Moist shoreline	-2.6a	-8.7a	-2.7a	-9.6a
Low Beach	-3.2b	-11.5b	-2.5a	-10.7b
High Beach	-4.4c	-12.3b	-4.3b	-11.6b

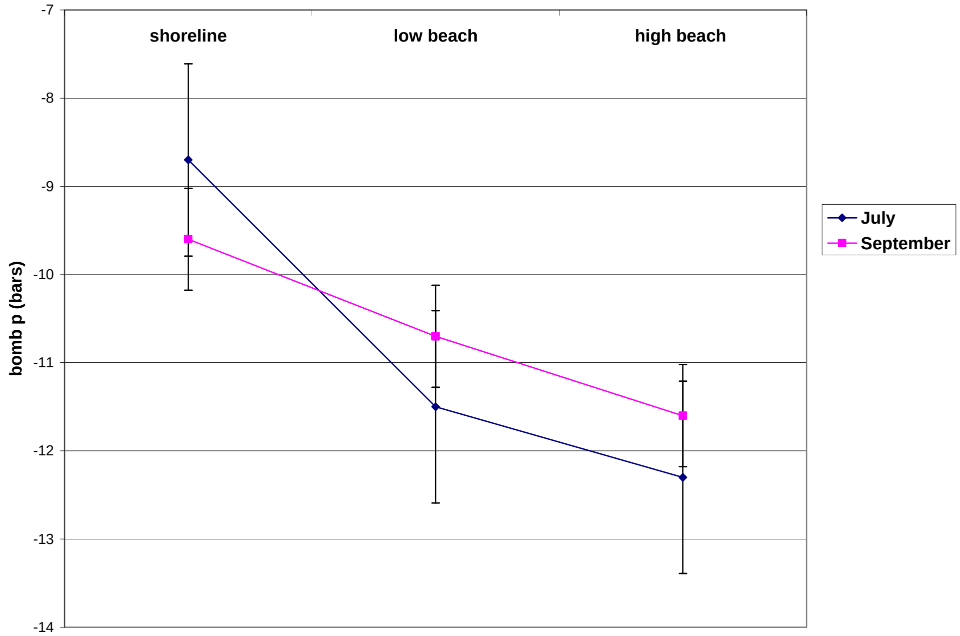


Figure 14. Mean midday water potentials (in bars) of TYC in selected habitats in July and September 2004. Data pooled from all sites. Bars indicate ± 1 SD.

Data from individual sites varied widely, suggesting there were no hydrological differences related to location. No significant differences in founder water potentials were measured at Avalanche or Zephyr Spit in July or September 2004 (Table 9). Both sites had high survivorship and are considered mesic (even though the latter is on the dry side of the Tahoe Basin). It may be that the high beach microhabitat at Zephyr Spit is actually subject to lake inundation during high water years and, therefore, has greater soil water availability than other high beach locations. Founder water potentials at Taylor Creek were not significantly different early in the season, but by September individuals in the moist shoreline were experiencing less stress. The pattern of founders having higher water potentials in the moist shoreline than in the low beach was maintained throughout the growing season at Sand Harbor. At Nevada Beach the difference between moist shoreline and low beach disappeared in September, but at that point founders in the high beach had significantly lower potentials than those in more mesic microhabitats.

Table 9. Midday water potentials (in bars) of TYC founders in selected microhabitats during A) July and B) September, 2004. Values in a column followed by different letters are significantly different (ANOVA p <0.001). na = data not available.

A) July 2004

microhabitat	Avalanche	Taylor	UTE	NV	Zephyr	Sand Harbor
Moist shoreline	-9.4a	-10.5a	-9.2a	-6.3a	-11.6a	-10.0a
Low beach	-10.5a	-11.2a	-12.6b	-11.7b	na	-13.0b
High beach	na	-11.7a	-12.0b	na	-13.3a	na

B) September 2004

microhabitat	Avalanche	Taylor	UTE	NV	Zephyr	Sand Harbor
Moist shoreline	-10.6a	-9.3a	-10.2a	-8.8a	-8.9a	-10.0a
Low beach	-9.3a	-11.9b	-13.0a	-9.7a	-9.4a	-12.8b
High beach	na	-12.5b	-11.8a	-13.7b	-8.6a	na

Differential survivorship in September within the four microhabitats at Upper Truckee East corresponded to mean midday founder water potentials (Figure 15). Mean survivorship in berm and moist shoreline were significantly greater and founder water potentials significantly higher than in the low beach or high beach. Competition for soil moisture from lupines and other vegetation in the low beach probably reduced survival in the low beach. This reduction was reflected in lower xylem water potentials, indicating that surviving plants were experiencing water stress from moisture competition and not from shading or space restrictions. The pattern at Nevada Beach also indicated a correlation between mean survivorship and mid-day water potentials, but was more typical of that observed at other sites where survivorship in the low beach and moist shoreline were significantly greater and water potentials significantly higher than the high beach (data not shown).

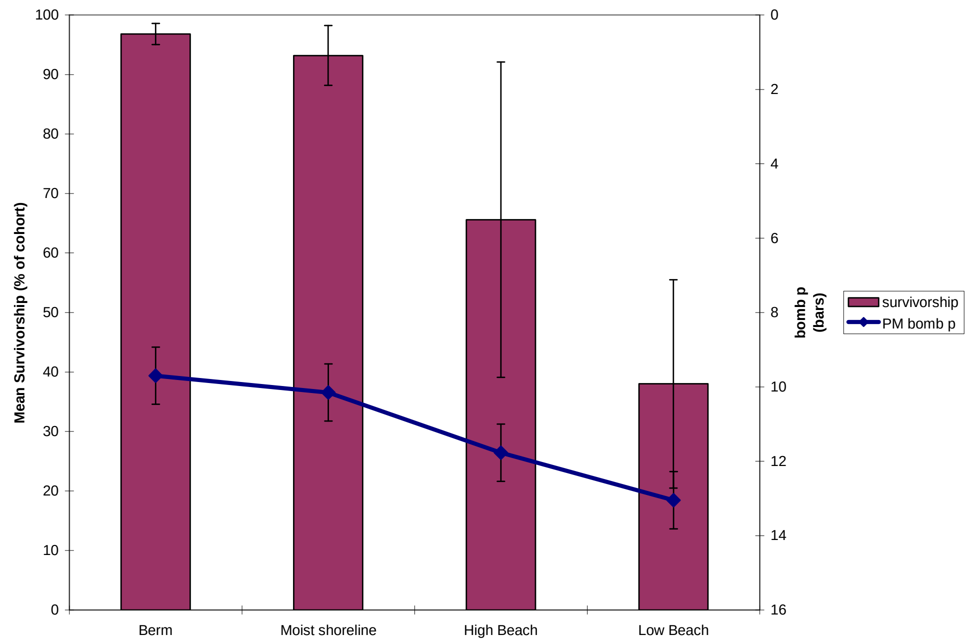


Figure 15. Mean founder survivorship and mean midday water potentials (bars X -1) of TYC in selected microhabitats at Upper Truckee East, September 2004. Bars indicate <u>+</u> 1 SD. Differences between survivorship in the low beach and the moist shoreline and berm microhabitats are significant (ANOVA $p < 0.001$).

A regression analysis indicates that mean midday water potentials may explain up to 30% of the variation in founder survivorship at all sites in September 2004 (Figure 16). Although the relationship is not strong, the overall pattern (mean survivorship decreases as water potentials decrease and water stress increases) is to be expected because herbaceous forbs thrive when well-watered and falter when stressed. TYC appears to be sensitive to relatively small changes in xylem water potential, perhaps because it lacks a well-developed mechanism for physiological acclimation (such as osmotic adjustment). This apparent lack of drought tolerance would be consistent with its ancestry since most cress species are limited to hydric soils. However, the fact that TYC occupies sandy and exposed microhabitats is certainly a phylogenetic deviation and it is clear that factors in addition to water status are also influencing survivorship.

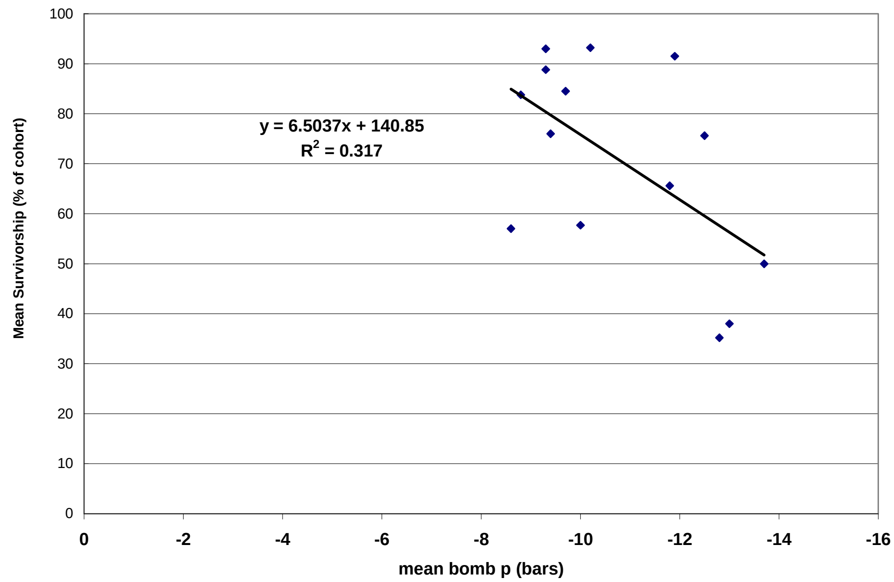


Figure 16. Regression of mean survivorship (%) on mean midday water potentials (bars) of TYC founders, September 2004. Data pooled from all sites.

3.6 Precision Seeding Experiment 2004

One month after sowing, very few seedlings had emerged from seeds in the plots at Upper Truckee East. No seedlings were present in any of the low beach or high beach plots. Two seedlings were present in one berm plot, and nineteen seedlings in one moist shoreline plot. However, small amounts of shifting of the beach sand surface (perhaps by wind or water) made it difficult to know for certain if seedlings were actually the products of sown seed. Only one of the seedlings was directly under the planting frame hole in the berm plot and some seedlings in the moist shoreline plot may have come from natural recruitment. Inspection around the area of the frames found new seedlings emerging beyond the edges of each plot. Even if all the seedlings were attributed to sown seed, the maximum of 24 seedlings emerging from a total sowing of 1,200 frame holes (each hole received more than one seed) would constitute very low germination and recruitment (2%). These results indicate that sowing TYC seed on the soil surface is an ineffective method for enhancing or creating TYC populations.

3.7 Demography of 2003 and 2004 Founders at 2003 Pilot Project Sites

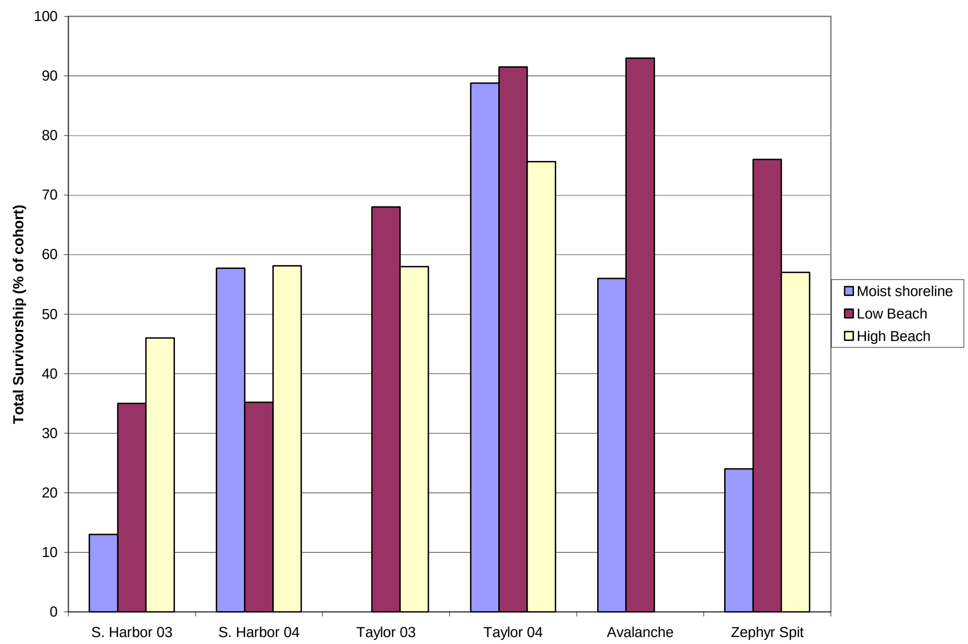
3.7.1. Overview

With sustained low lake levels during 2004, nearly 90% of the 2003 founders that survived to the end of the first growing season (September 2003) were alive at the end of the second (September 2004). There were almost 750 established second year-olds thriving at four sites from the 2003 pilot project. Survivorship within this 2003 cohort was still lowest at Sand Harbor and highest at Avalanche (Figure 17A). The effects of microhabitat on survivorship were still evident at all sites with best demographic performance in low beach and poorest performance in high beach.

Total first year survivorship of the 2004 cohorts at Sand Harbor and Taylor Creek was higher than it had been for the 2003 installation, increasing from 27 to 43% at Sand Harbor (2003 and 2004, respectively) and from 58 to 77% at Taylor Creek. This was partially due to less inundation in the moist shoreline, but there was also improved survivorship in the high beach at both sites, possibly indicating greater water availability because of higher lake levels in 2004.

The number of founders from the two cohorts (2003 and 2004) that survived to reproduce is an important indicator of the potential of reintroduced plants to persist and form populations of value to conservation. Survivorship to reproduction in September 2004 was greater than 50% in

A)



B)

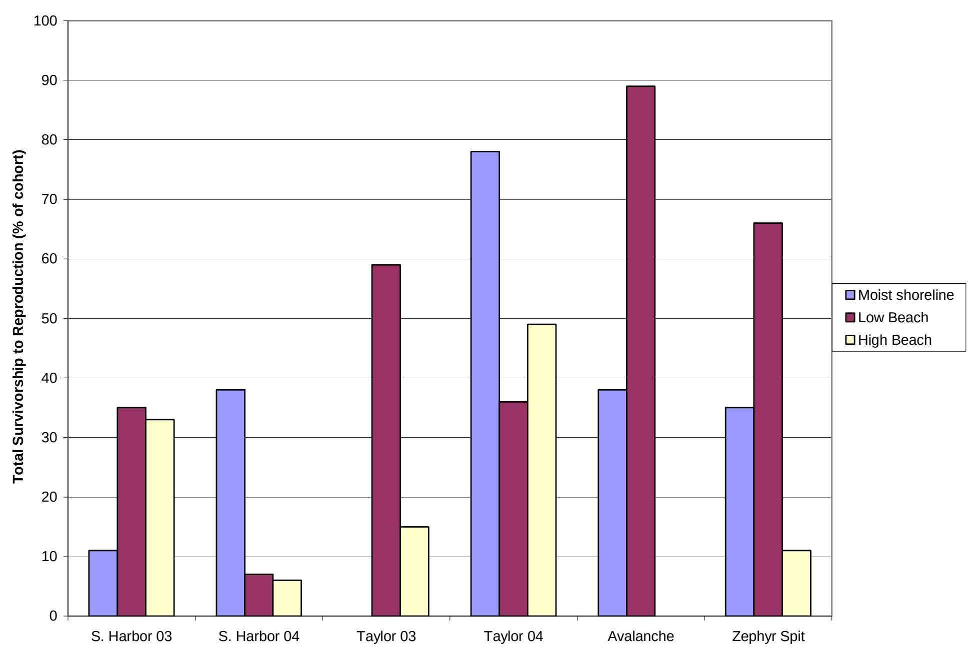


Figure 17. Overall **A)** survivorship and **B)** survivorship to reproduction in September 2004. of the 2003 (two year-old) and 2004 (one year-old) cohorts at multiple sites and in different microhabitats.

moist microhabitats (e.g. moist shoreline) and less than 50% in drier microhabitats (e.g. high beach) regardless of site location (Figure 17B). Furthermore, two year-old founders at Taylor Creek and Sand Harbor had much higher survivorship to reproduction in 2004 (58 and 35%, respectively) than did one year-olds (36 and 7%) in the same low beach microhabitat in the same year. This indicates that founders established in moist microhabitats will be more likely to reproduce in subsequent years and more likely to leave behind progeny to maintain the population. The apparent fact that older individuals are more likely to persist and reproduce in years with poor recruitment highlights the importance of age structure in a population. Furthermore, outplanting in multiple years at the same site exposed founders to both optimal (2003) and suboptimal (2004) conditions for long-term persistence, and the differential performance of the two cohorts highlights the importance of founder cost averaging (i.e spreading the risk across years).

3.7.2. Avalanche

Overall Performance: With sustained low lake level during 2004, a majority of the founders from 2003 were still alive, with nearly 75% (227 individuals) reappearing and surviving to September 2004. The proportion of surviving two year-olds that reproduced increased 30% from the previous year to 86%. Total seed production for the site (57,365 seeds,) was about 22% higher than in 2003. However, plantlet production was about 35% lower. Approximately 36% of the population (107 individuals) exhibited clonal growth, producing a total of 596 "plantlets" (compared to 868 in 2003). The reduction in cloning may be a consequence of an increase in energy allocation to seed output.

Effect of Microhabitat: Two microhabitats were present at Avalanche; moist shoreline and low beach. The moist shoreline was between 6,224.9 – 6,225.7 feet in rows 1-14 in Plot 1. During 2003, the first 5 rows in plot 1 were subject to inundation and intense wave action early in June and many founders planted within 2 meters of the shoreline were soon washed away. Although only rows 1-5 were considered moist shoreline for the 2003 analysis, the definition was expanded to include rows 6-14 for 2004. Plants in these rows occurred in a beach trough characterized by constantly saturated soils and dense sprouts of had emerged over the last few years of lake recession. Low beach habitat, found in rows 15-24 in Plot 1 and all of Plot 2, occurred at 6,225.8 – 6,228 feet. Rows 8-10 in plot 2 were technically above the low beach cut-off of 6,228 feet, but they were included in the low beach microhabitat for the analysis because the entire beach at Avalanche is inundated during high lake years and no high beach refuge is available.

Survivorship of two year-old founders in the moist shoreline microhabitat was 69% in July and August, dropping to 56% by September (Figure 18). Of these survivors, 68% were reproductive. Two year-old founders performed better in the low beach microhabitat where they were not subject to inundation or wave action. Survivorship was 96% in July, barely decreasing to 93% by September. Nearly 96% of the two year-old founders were reproductive. While vegetative reproduction was almost equivalent in the two microhabitats (286 plantlets were counted in low beach and 268 in the moist shoreline), plant canopy size and seed output was dramatically higher in low beach (Table 10). Plants in the low beach had an average canopy area of 220 cm^2 and produced a total of 57,170 seeds (742 seeds output per founder). In the moist shoreline, saturated conditions may have inhibited plant growth. Average plant canopy area was only 28 cm^2 and all individuals produced only 1,395 seeds.

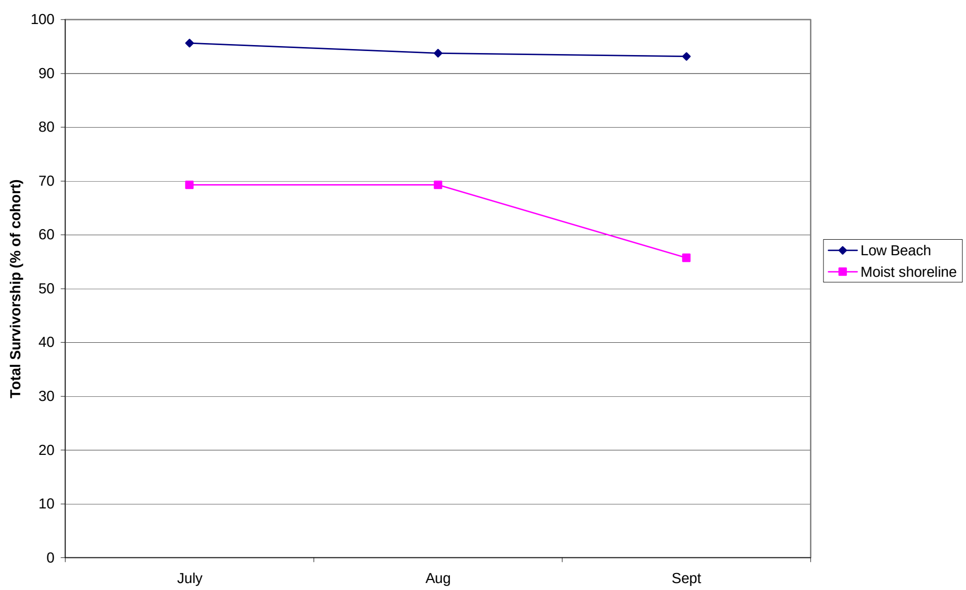


Figure 18. Survivorship of the 2003 (two year-old) cohort of TYC in two microhabitats at Avalanche Beach in 2004.

Table 10. Mean canopy area, mean seed output (#/founder), total seed production (#/microhabitat) and total plantlet production (#/microhabitat) of the 2003 (two year-old) cohort of TYC at Avalanche in September 2004. Mean values in a column followed by different letters are significantly different (ANOVA $p<0.0001$).

Microhabitat	# (and proportion) of Reproductive Plants	Mean Canopy Area (cm2)	Mean Seed Output (#/founder)	Total Seed Production (# /habitat)	Total Plantlet Production (#/habitat)
Moist shoreline	53 (68%)	28a	73a	1,395	**268**
Low beach	143 (96%)	220b	742b	57,170	**286**

3.7.3. Zephyr Spit

Overall Performance: There was more two year-olds present in the 2 plots at Zephyr Spit during September 2004 than there were in September 2003. Of the original founders, nearly 60% (171 individuals) had survived to September 2004 (four more than in 2003). Total seed production for the site was estimated at 34,865 seeds, with 58% of surviving founders reaching reproductive maturity by September. The average canopy area of reproductive individuals was 140 cm^2 and the average seed output was 430 seeds per founder. In contrast to Avalanche beach, where seed output increased and plantlet production declined, seed output was 38% lower at Zephyr Spit than in 2003. A total of 90 founders produced 1209 plantlets, an increase of 26% compared to 2003.

Effect of Microhabitat: Three microhabitats were present at Zephyr Spit; moist shoreline, low beach, and high beach. The moist shoreline (6,224.9 – 6,225.6 feet) was subject to protracted inundation and wave action and many of the plants were washed away soon after outplanting in 2003. Low beach habitat was present in rows 6-13 in plot 1, between 6,225.8 – 6,226.9 feet. All of plot 2 was high beach habitat (6,228 – 6,229.8 feet).

Over the 2004 growing season, survivorship of two year-olds was greatest in the low beach (Figure 19) where 76% of the founders survived to September and 86% (63 individuals) produced fruit. Founders in the moist shoreline had only 24% survivorship, but 91% (21 individuals) produced fruit. Vegetative reproduction was similar in both microhabitats, averaging 500 and 692 plantlets (Table 11). In the high beach 57% of founders survived, but reproductive output was significantly lower. High beach founders were significantly smaller, produced less seed, and showed less vegetative reproduction (17 plantlets) than founders in other microhabitats. However, peak reproduction in the high beach actually occurred during July when 50% of the living plants were in fruit, so many of plants had senesced by September.

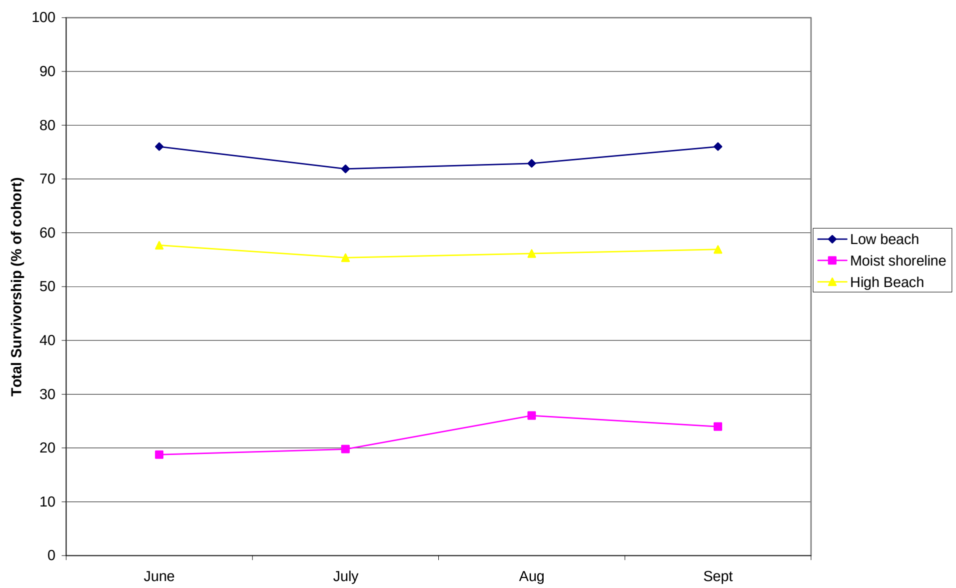


Figure 19. Survivorship of the 2003 (two year-old) cohort of TYC in three microhabitats at Zephyr Spit in 2004.

Table 11. Mean canopy area, mean seed output (#/founder), total seed production (#/microhabitat) and total plantlet production (#/microhabitat) of the 2003 (two year-old) cohort of TYC at Zephyr Spit in September 2004. Mean values in a column followed by different letters are significantly different (ANOVA p<0.0001).

Microhabitat	# (and proportion) of Reproductive Plants	Mean Canopy Area (cm2)	Mean Seed Output (#/founder)	Total Seed Production (# /habitat)	Total Plantlet Production (#/habitat)
Moist shoreline	21 (91%)	116a	344a	6,890	**500**
Low beach	63 (86%)	147a	445a	26,712	**692**
High beach	14 (19%)	27b	85b	851	**17**

3.7.4. Sand Harbor

3.7.4.1. 2003 (two year-old) cohort in 2004

Overall Performance: Survivorship of founders was the lowest at Sand Harbor when compared to the other reintroduction sites. Only 27% (78 individuals) of the 2003 founders were alive in September 2003, but nearly 90% (70 plants) of these were present in September 2004 as two year-olds. However, these represent only 24% of the original founding cohort of 297 individuals. A total of 64 individuals (91%) were reproductive in September 2004. These plants had an average canopy area of 213 cm^2 (± 154), output an estimated 661 seeds per plant (± 636) and produced a total of 37,686 seeds at the site. At least 30 individuals produced a total of 129 plantlets.

Effect of Microhabitat: Three microhabitats were present at Sand Harbor; moist shoreline, low beach, and high beach. Unlike all other sites, survivorship was actually greatest in the high beach habitat (6,228 – 6,228.6 feet) where 46% of the original planting survived to a second September (Figure 20). The shoreline (6,224.4 – 6,225.6 feet) was subject to intense inundation and wave action and many of the plants in the first 5 rows of the plots were washed away in 2003. Only 13% (10 plants) of the original 2003 cohort reappeared in the moist shoreline and survived to September 2004. In low beach habitat (6,224.4 – 6,225.7 feet) nearly 35% of the 2003 founders survived to September 2004.

Of the 10 two year-olds in the moist shoreline, 9 (90%) fruited and produced seed in September 2004. These founders were, however, significantly larger (mean canopy area = 346 cm^2) and made many more seed per plant (1,140 seeds per founder) than those in other microhabitats (Table 12). Seed production was not estimated in 2003 (a monitoring error), so no comparison between the years is possible. Plantlet production in the moist shoreline was similar to that in the low beach (66 and 62 plantlets, respectively). In the high beach, only one plantlet was present, possibly a symptom of reduced resource availability and growth due to water stress.

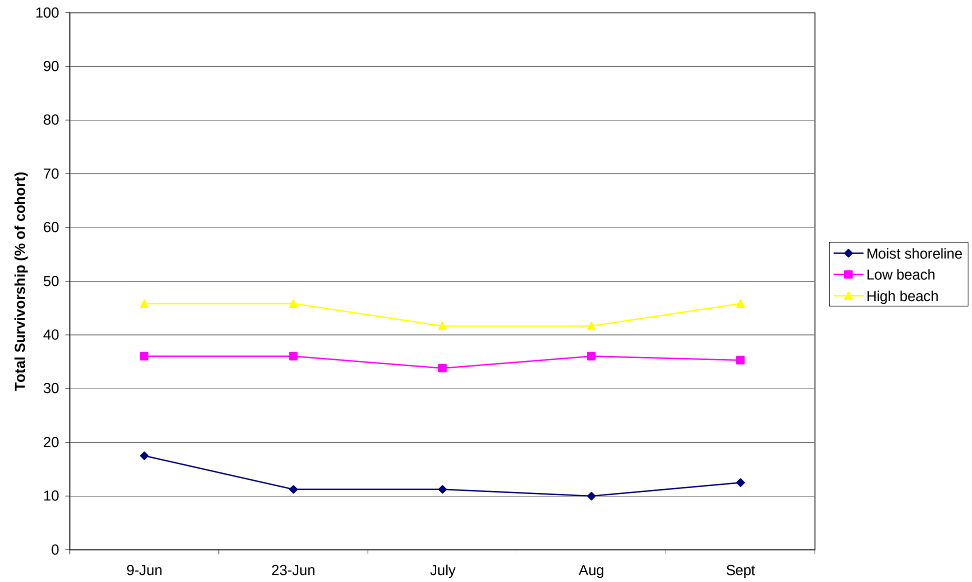


Figure 20. Survivorship of the 2003 (two year-old) cohort of TYC in three microhabitats at Sand Harbor in 2004.

Table 12. Mean canopy area, mean seed output (#/founder), total seed production (#/microhabitat) and total plantlet production (#/microhabitat) of the 2003 (two year-old) cohort of TYC at Sand Harbor in September 2004. Mean values in a column followed by different letters are significantly different (ANOVA $p<0.05$).

Microhabitat	# (and proportion) of Reproductive Plants	Mean Canopy Area (cm2)	Mean Seed Output (#/founder)	Total Seed Production (# /habitat)	Total Plantlet Production (#/habitat)
Moist shoreline	9 (90%)	346a	1140a	9,204	66
Low beach	47 (98%)	197b	616b	26,467	62
High beach	8 (73%)	97b	336b	2,015	1

3.7.4.2. 2004 (one year-old) cohort in 2004

<u>Overall Performance:</u> Total survivorship of the 2004 cohort (43%) was higher than the 2003 cohort (27%) in September 2004, probably because the moist shoreline was not as disturbed by wave action or inundation in 2004 as it had been in 2003. However, reproduction of the 2004 cohort was much less than the 2003 cohort. Of the 2004 cohort survivors, only 34% (41 individuals) were reproductive in September 2004, producing a total of 6,856 seeds (one sixth of the 2003 cohort at this time). These individuals had a

mean canopy area of only 85 cm^2 (± 40), on average 60% smaller than canopies of the 2003 cohort. A low mean seed output of 236 seeds per founder (±1322 seeds) was likely due to the small size of plants in this dry year of low lake level. Vegetative reproduction was also less, with 22 individuals producing only 50 plantlets in all (less than half of the 2003 cohort).

Effect of Microhabitat: The pattern of survivorship of the 2004 cohort (one year-olds) was unusual (Figure 21). Founders in the low beach experienced a sharp decrease from 87% in June to only 37% in July 2004. The high beach experienced smaller decline, from 90% in June to 60% in July. Relatively high survivorship in the high beach microhabitat has generally not been observed at other sites around the lake. Even more unusual was that the numbers of plants in the moist shoreline appeared to increase from June to September. Those inundated early in the season (June) may have only been covered with sand and not washed away. There were recorded as "missing" in stead of "disappeared" (as in the CS), only to "reappear" later in the season when new shoots emerged from persistent rootstock.

Although survivorship was equivalent in the moist shoreline and high beach habitats (both 58%) reproduction was markedly different (Table 13); 66% (27 plants) of surviving plants in the moist shoreline produced a combined total of 5,063 seeds (389 seeds per founder ± 187) in September 2004, but only 2 individuals (11%) in the high beach had any fruit at the same time. However, peak reproduction in the high beach occurred earlier, when 6 individuals (21%) made fruit in June. Plants in high beach habitat remained small through the season, perhaps experiencing levels of water stress that reduced resources for seed production. In the low beach, a total of 12 individuals (19%) produced an estimated 1,793 seeds (448 seeds per founder ± 546) but the peak occurred in August (when 34% were reproductive).

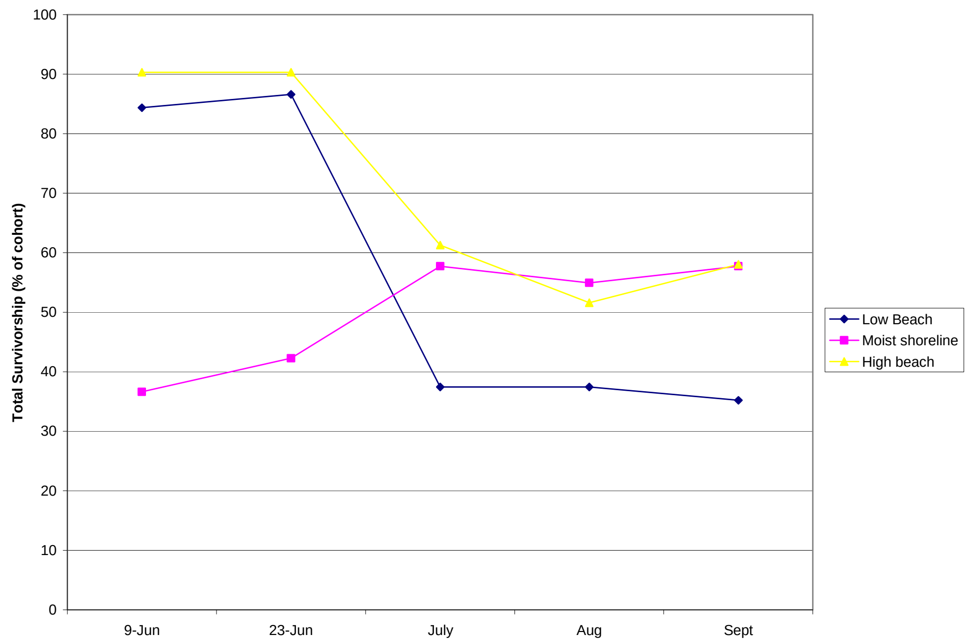


Figure 21. Survivorship of the 2004 (one year-old) cohort of TYC in three microhabitats at Sand Harbor in 2004.

Table 13. Mean canopy area, mean seed output (#/founder), total seed production (#/microhabitat) and total plantlet production (#/microhabitat) of the 2004 (one year-old) cohort of TYC at Sand Harbor in September 2004. Mean values in a column followed by different letters are significantly different (ANOVA $p<0.05$).

Microhabitat	# (and proportion) of Reproductive Plants	Mean Canopy Area (cm2)	Mean Seed Output (#/founder)	Total Seed Production (# /habitat)	Total Plantlet Production (#/habitat)
Moist shoreline	27 (66%)	86a	202a	5,063	33
Low beach	12 (21%)	75a	448a	1,793	15
High beach	2 (11%)	11.5b	0	0	1

3.7.5. Taylor Creek

3.7.5.1. 2003 (two year-old) cohort in 2004

Overall Performance: A total of 279 founders of the 2003 cohort, or 52% of the original planting, survived as two year olds to September 2004. There were 316 founders alive at the end of the 2003 season, so this represents a transition probability of 88%. The wintertime loss was entirely the result of Taylor Creek inundating and eroding the moist shoreline plot. Nearly 80% of the survivors reproduced in 2004, but total estimated seed production for the site (63,113 seeds) was just over half of what it had been in 2003 (119,085 seeds). Mean seed output (394 seeds per founder) was about 25% lower than 2003 (532 seeds per founder) and plants were about 40% smaller (mean canopy area of 105 cm) in 2004.

<u>Effect of Microhabitat</u>: Three microhabitats were monitored at Taylor Creek in 2004; low beach, high beach, and dune trough (due to complete mortality of the 2003 cohort in the moist shoreline and meadow). What was called the beach trough plot 2 in the 2003 pilot analysis was relabeled as low beach (conforming to the definitions in Table 1). Plot 3, called dune habitat in 2003, was more precisely divided into high beach (>6,228 ft) and dune trough (6,224.6-6,226 ft). The moist shoreline plot established in 2003 was destroyed by the movement of Taylor Creek over the winter when it took a sharp turn towards the west and swept away Plot 1. Founders in the meadow habitat in plot 5 did not survive past June 2003, and no plants were present at the beginning of 2004 season. The other microhabitats were not disturbed by Taylor Creek and the small trough of still water extending through the low beach was also present at the beginning of 2004. Survivorship was fairly constant over the season and similar in all three microhabitats, ranging from 58% in the low beach to 68% in both the dune trough and high beach (Figure 22).

Over 80% of founders reproduced in both the dune trough and the low beach (Table 14). Mean seed output and total seed production were similar in these microhabitats. Over 1,000 plantlets were counted in the low beach but only 31 in the dune trough (perhaps due to greater depth to the water table) .In the high beach, however, only 6 individuals, or 25% of the survivors, were in fruit in September 2004 and no plantlets were produced.

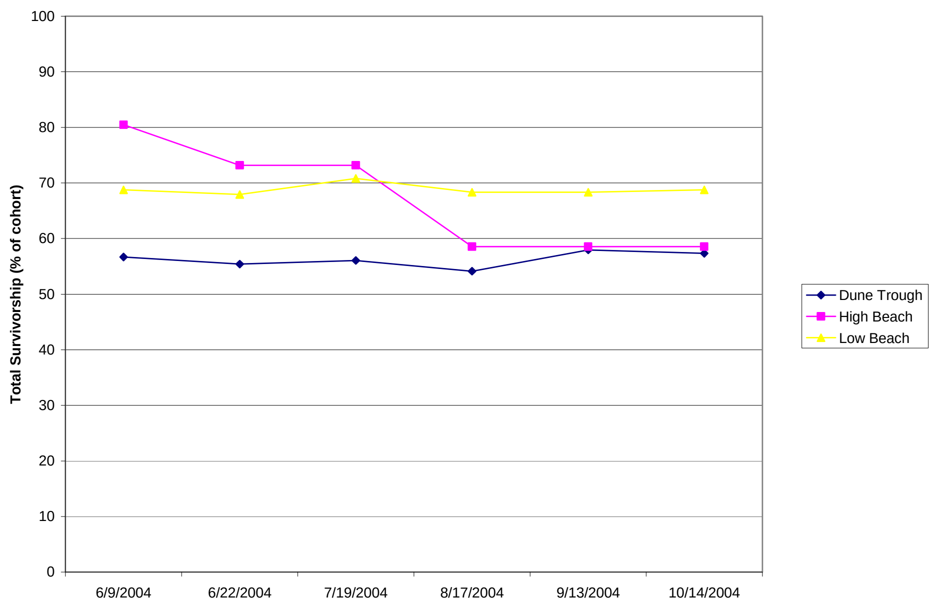


Figure 22. Survivorship.of the 2003 (two year-old) cohort of TYC in three microhabitats at Taylor Creek in 2004.

Table 14. Mean canopy area, mean seed output (#/founder), total seed production (#/microhabitat) and total plantlet production (#/microhabitat) of the 2003 (two year-old) cohort of TYC at Taylor Creek in September 2004. Mean values in a column followed by different letters are significantly different (ANOVA p<0.05). na = data not available

Microhabitat	# (and proportion) of Reproductive Plants	Mean Canopy Area (cm2)	Mean Seed Output (#/founder)	Total Seed Production (# /habitat)	Total Plantlet Production (#/habitat)
Dune trough	74 (81%)	121a	417a	25,016	31
Low beach	142 (86%)	99a	386a	37,447	1,127
High beach	6 (25%)	na	na	na	0

3.7.5.2. 2004 (one year-old) cohort in 2004

Overall Performance: The 2004 cohort had nearly 20% greater survivorship than the 2003 cohort in its first year. A total of 393 founders, or 77% of the 2004 cohort, survived to

September 2004, compared to only 58% of one year olds surviving in 2003. However, the 2004 founders were very small and mean seed output was relatively low. The mean canopy area (51 cm^2) of the 2004 founders was 72% smaller than in 2003, while mean seed output (180 seeds per founder) was 66% less. Although 65% of the survivors reproduced in September 2004, they produced an estimated 25,395 seeds, just over 20% of the seed production in 2003 (119,085 seeds).

<u>Effect of Microhabitat:</u> Five microhabitats were outplanted with founders at Taylor Creek in 2004: moist shoreline, low beach, high beach, dune trough, and meadow. The shift in some microhabitat definitions for the 2004 analysis prevents strict comparison with the 2003 cohort. Overall, the pattern of survivorship varied widely among the five microhabitats (Figure 23). As previously observed during 2003, all founders in the meadow were dead by July, confirming that this microhabitat is unsuitable for TYC. By September, the lowest survivorship was in the dune trough (59%) followed by the high beach (76%). Founders in the moist shoreline and low beach had uniformly high rates of survivorship (89 and 92%, respectively).

Founders in the moist shoreline and dune trough had significantly greater canopy areas and seed output than those in the low or high beach (Table 15). The high survivorship and robust reproduction in the moist shoreline indicate that this is physiologically suitable habitat at Taylor Creek. However, it also most likely to be inundated or eroded by changes in creek hydrology. The dune trough is inherently more stable than the moist shoreline and is available for colonization in low or high water years at Taylor. Despite lower survival and proportion of survivors reproducing (44%), founders in the dune trough were larger and had high seed output. Although they are at a competitive disadvantage with species that grow tall along the margins of water in the trough's lagoon, plants in the adjacent natural population are very persistent where the sand is open and not too high above the water table. Overall, the dune trough microhabitat at Taylor Creek may be optimal for persistence in the face of environmental stochasticity.

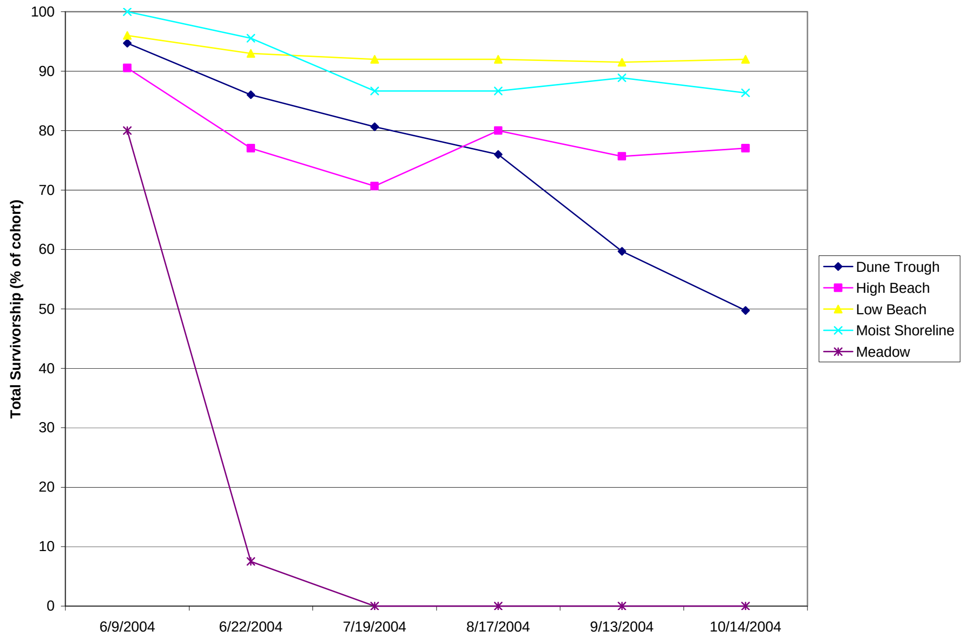


Figure 23. Survivorship of the 2004 (one year-old) cohort of TYC in three microhabitats at Taylor Creek in 2004.

Table 15. Mean canopy area, mean seed output (#/founder), total seed production (#/microhabitat) and total plantlet production (#/microhabitat) of the 2004 (one year-old) cohort of TYC at Taylor Creek in September 2004. Mean values in a column followed by different letters are significantly different (ANOVA p<0.001).

Microhabitat	# (and proportion) of Reproductive Plants	Mean Canopy Area (cm2)	Mean Seed Output (#/founder)	Total Seed Production (# /habitat)	Total Plantlet Production (#/habitat)
Moist shoreline	35 (87%)	82a	272a	7,087	57
Dune trough	50 (44%)	74a	352a	9,527	31
Low beach	72 (75%)	39b	106b	7,671	832
High beach	31 (55%)	32b	61b	924	0

3.8 Effects of Human Disturbance

In 2004, all sites were partially or fully enclosed with fences except for Avalanche (the site was not fenced in 2003 due to its remote location). Fencing helped to reduce impacts from recreational activities among the sites, but three of the enclosures were vandalized during the season. At Taylor Creek, the wire flags marking plants in the dune trough plot within the permanent fence were removed some time in August. The tight spacing of the 2003 and 2004 cohort made it difficult to re-place the flags correctly and consequently the August data could not be used in analysis. Some uncertainty remained over plant identity in September, but the summary data was sound. The temporary fencing in the low beach at Zephyr Cove was cut early in the season. No plants were harmed and the USFS repaired the fence quickly. The fence at Nevada Beach also required repairs during the season.

At Upper Truckee East, temporary orange construction fencing was installed immediately after the June outplanting and the fence was cut within two weeks. The CTC replaced the orange fence with permanent plastic-wrapped wire and wood post fencing. This fence remained intact throughout the season; however, signs of dogs and footprints were evident in the plot at every monitoring period.

Maintaining fencing throughout subsequent experimental plantings will be important for data collection continuity. Positive identification of individual plants is required for detecting initial vigor related or genotype-related causes of differential founder survival and it is critical to determining founder longevity and decay curves for reproductive characters.

4.0 Discussion

4.1 Addressing Key Management Questions (KMQs)

The KMQs that guide conservation and restoration research on TYC (Pavlik and O'Leary 2002, Table 16) focus research on generating information of immediate value to decision-making within the adaptive management framework. While the 2003 Pilot Project addressed primarily KMQ 3, the 2004 experimental reintroduction addresses all 5 of the KMQs. Results of the 2004 research are summarized below in relation to each question.

Table 16. Key Management Questions for guiding conservation and restoration research on Tahoe Yellow Cress (Pavlik and O'Leary 2002).

1) Can TYC populations occupy any site around the lake margin that has sandy beach habitat?
2) Are there ecosystem factors that can affect TYC performance within an occupied site or microhabitat?
3) Can TYC populations be created or enlarged in order to restore the self-sustaining dynamics of the species?
4) Can any TYC genotype perform equally well at any appropriate site?
5) Can TYC microhabitats/places be found or created that are less likely to be adversely disturbed despite high visitor use or intense shoreline activity?

KMQ 1) Can TYC occupy any site around the lake that has sandy beach habitat?

The first KMQ focuses on differences among sites that affect performance of TYC. Through an environmental characterization of outplanted sites we can determine if observed differences in demographic performance (e.g. survivorship and reproduction) is related to factors such as beach topography, hydrology, or the presence of shore zone vegetation. The overarching null hypothesis is that TYC performance is equivalent at all sites. This hypothesis is rejected by the fact that survivorship around the lake varied widely between sites in both 2003 and 2004. In 2003, survivorship (of one year-olds) ranged from 27% at Sand Harbor to 86% at Avalanche Beach. In 2004, it ranged from 43% at Sand Harbor to 77% at Taylor Creek. Despite year to year (stochastic) variation, survivorship was consistently lower at Sand Harbor in both years.

A second, more narrowly defined hypothesis related to KMQ 1 is as follows: For a given microhabitat around the lake, TYC performance will be the same across all sites in the same year. We chose to characterize microhabitat by elevation and defined three that were present at most sites; moist shoreline, low beach, and high beach. Among the 2003 cohort, survivorship in the moist shoreline varied from only 13% at Sand Harbor to 56% at Avalanche. There was also large variation in survivorship (35-93%) in the low beach among the sites. Survivorship in the high beach was less variable, ranging from only 46-58% among all sites. It is possible that in a low lake level year, fluctuations in the position of the waterline have a very small influence on the high beach. This would tend to equalizes demographic performance among the sites under these conditions.

Among the 2004 cohort, TYC performance in a given microhabitat also varied among sites. There was uniformly high survivorship in both the moist shoreline and the low beach at Taylor and Nevada beaches, but very low survivorship in the low beach at Upper Truckee East (UTE) and Sand Harbor. Low survival at Sand Harbor is difficult to explain, but high mortality at UTE was likely due to the competitive effects of lupine (*Lupinus lepidus*). By early August, lupine cover on the low beach averaged 61%, while it was only 3-5% on the high beach.

Variability in survivorship in the high beach among the 2004 cohort doubled from what it was measured in 2003, with means ranging from 50% at Nevada Beach to 75% at Taylor Creek. The increase in variation may be partially explained by the fact that the high beach in 2004 encompassed a greater elevation range than it did in 2003. The plants in the high beach plot at Nevada were at 6,229-6,230.6 feet, while the high beach at Taylor occupied a narrow band just above the high water line of 6,228 feet between 6,628.5-6,628.7 feet.

Given the results to date, the answer to this KMQ is that all sandy sites around the lakeshore are not equivalent with respect to providing adequate conditions for TYC populations. Managers cannot, therefore, assume site equivalency when issuing permits or prescribing mitigation measures that affect the species.

KMQ 2) Are there ecosystem factors that affect TYC performance within an occupied site?

This KMQ focuses on the suitability of microhabitats within a given site. The null hypothesis is that TYC performance will be the same at all topographic positions within a site. Data from 2003 and 2004 demonstrate that, in general, survivorship varies greatly between microhabitats. At Nevada Beach and UTE, survivorship among microhabitats is statistically different. TYC performance, as measured by survivorship, was significantly better in the moist shoreline than the low or high beach microhabitats at both UTE and Nevada. Reproduction followed a similar pattern. At UTE, significantly more plants reproduced in the berm and moist shoreline than in the low or high beach. At Nevada, the difference in plant performance between microhabitats was more pronounced as reproduction was significantly higher in the moist shoreline than in the low beach and the high beach.

The main ecosystem factor being tested in this reintroduction experiment was depth to the water table within different microhabitats (although disturbance by waves and inundation were also observed). Microhabitats were categorized according to elevation, based on the assumption that the water table is at the level of Lake Tahoe and, therefore, the height of a plot above the lake is equivalent to the depth of the water. The water potential monitoring component attempted to quantify plant response to microhabitat by measuring plant water status. Since plant water status reflects the ambient soil and atmospheric moisture conditions, it provides a direct assessment of water availability among TYC microhabitats.

A regression analysis indicated that mean midday water potentials explained up to 30% of the variation in founder survivorship at all sites by September 2004. Although the relationship is not strong, the overall pattern (mean survivorship decreasing as water potentials decreased) is to be expected because many because herbaceous forbs thrive when well-watered and falter when stressed. TYC appears to be sensitive to relatively small changes in xylem water potential, perhaps because it lacks a well-developed mechanism for physiological acclimation (such as osmotic adjustment). This would be consistent with its ancestry since most cress species are limited to hydric soils. However, occupancy of sandy and exposed microhabitats is certainly a phylogenetic deviation and it is clear that factors in addition to water status are also influencing survivorship of TYC.

Given the results to date, the answer to this KMQ is that all microhabitats at a given sandy site are not equivalent with respect to providing adequate conditions for TYC populations. Microhabitats that provide a shallow depth to the water table that are protected from lake level and human disturbance are more likely to allow high survivorship and reproductive output of TYC. Managers cannot, therefore, assume microhabitat equivalency when issuing permits or prescribing mitigation measures that affect the species.

KMQ 3) Can TYC populations be created or restored in order to enhance the self-sustaining metapopulation dynamic?

This KMQ addresses those factors that might influence the success of outplanting as a management tool for creating new populations or enhancing existing ones. Whether or not such actions can affect the metapopulation dynamic must be subsequently addressed at the landscape level by documenting colonization and extirpation events around the lake. Microsatellite DNA techniques can also be used to address the origins and relatedness of metapopulations.

In 2003 we made a preliminary study of site and plant factors that might influence restoration success. Site factors were broadly described as different "microhabitats" that mainly reflected position on the beach (i.e. "moist shoreline" occurred within 2m of the lake and "high beach" included everything else). Plant factors were related to either greenhouse condition (initial founder vigor at the time of planting) or the genetic stock of the founder. We observed that 1) site factors influenced TYC performance at all sites, 2) the initial vigor of the founding plant influenced TYC performance at 3 of 4 sites, and 3) the source population of the founder did not appear to influence TYC performance.

In 2004, the site factor of microhabitat strongly influenced plant performance at all sites, while the plant factors of initial vigor and source population did not influence demographic performance. Given the low amount of genetic diversity detected in multiple studies (summarized in the CS), the greater importance of site factors in creating or enlarging populations is not surprising. Nearly 90% of the 2003 founders that survived to the end of the first season transitioned into the second season and survived to September. This represents a return rate of 54% on our initial investment of 2003 founders. Such a high rate of return may indicate that we successfully created a population at Sand Harbor and enhanced existing populations at Avalanche, Zephyr Cove, and Taylor Creek. However, the availability of favorable ecosystem factors (e.g. moisture, shallow depth to water table) decreased in 2004 when lake level dropped from 6,224 feet to 6,223 feet. If lake level had risen, we would have expected the rate of return on our investment to diminish because TYC persistence has been shown to be inversely related to lake level (Pavlik et al. 2002). The importance of site factors in restoration success is, therefore, related to the probability of inundation and erosion by the lake. It may follow from the principle of founder-cost averaging that it is a good strategy to distribute restoration efforts across years (that is to outplant founders in multiple years) because of the year to year uncertainty of lake level and the associated difficulty of choosing an optimum year for outplanting all available founders.

Given the results to date, the answer to this KMQ is that reintroduction to certain microhabitats at a given sandy site appears to be a practical and effective tool for creating and enhancing TYC populations. Age structuring and founder-cost averaging appear to be beneficial approaches for promoting better demographic performance and population persistence. Managers can, therefore, prescribe carefully designed, executed and monitored reintroduction for purposes of conservation, restoration and mitigation.

KMQ 4) Can any TYC genotype or gene pool perform equally well at any site?

This KMQ addresses whether particular genotypes or multiple seed sources are necessary for restoration success. The null hypothesis is that TYC from all seed sources perform equally well. Data from 2003 suggested that seed source did not influence TYC demographic performance. Data from the 2004 replicated experimental reintroductions at Nevada Beach and Upper Truckee East strongly suggests that founder population sources (i.e. genetics) do not play a significant role in the survival of outplanted seedlings. Mean survivorship of founders in September 2004 from different seed sources was not significantly different within any microhabitat at either site. In order to retain unique alleles that may be present in founders from certain source populations (see Hipkins and De Woody 2004), it would be ideal to mix seeds from many locations for propagation purposes, but founder seed sources not need to be tracked during restoration efforts.

Given the results to date, the answer to this KMQ is that any TYC genotype or gene pool (source population) appears to perform equally well at any site and in any optimal microhabitat. Therefore, managers do not have to insist upon certain design features to compensate for genetic factors when reintroduction is for conservation, restoration or mitigation purposes

KMQ 5) Can TYC habitats been found or created that are less likely to be adversely disturbed despite high visitor use or intense shoreline activity?

This KMQ focuses on whether adverse impacts on TYC from recreational use can be mitigated. The null hypothesis is that given equal levels of recreational use, the presence or absence of fencing or signage does not affect TYC performance. The only way to test this statistically is to set up an experiment at a single site with a set of replicated plots with fences and a second set without fences (or signs). This scenario is unrealistic from a management perspective and we are forced to infer from observational monitoring data gathered during the last two years. During that period fencing and signage were largely effective at minimizing disturbance to the pilot project and experimental reintroduction efforts. Very few TYC plants died because of incursion into the plots by humans or their animals, although some monitoring data was compromised at Taylor Creek. Fencing at three of the enclosures (Taylor Creek, Upper Truckee East, and Zephyr Cove) was vandalized during the course of the projects and there were signs of dogs and footprints were evident in the partial enclosure at Upper Truckee East on every sampling date.
Given the results to date, the answer to this KMQ is that humans and their animals gravitate to the locations of restoration activities and, therefore, there will always be a probability of disturbance. Even remote, hard to access locations (e.g. Avalanche) can be subjected to recreational impacts. Therefore, managers will need to maintaining fencing during all conservation, restoration, and mitigation projects, especially those requiring the collection of monitoring data.

5.0 Conclusions

The following conclusions are presented as bullets that summarize the main results for each of the report sections.

Nursery propagation

- 3,300 founders from 8 seed sources were available for outplanting in May 2004.
- Plant quality was relatively low; 48% of founders were classified as Low vigor and 52% were classified as High vigor.

Plant Installation

- 1,424 founders were outplanted at 4 sites in 2003.
- 2,814 founders were outplanted at 4 sites in 2004.
- Total of 4,238 founders were outplanted at 6 sites over 2 years.
-

Demography of 2004 Experimental Populations

At Nevada Beach

- 582 founders from three seed sources (Taylor Creek, Cascade, and Tahoe Meadows) were planted in June in 3 microhabitats: moist shoreline, low beach, high beach
- 75% of founders survived to September.
- Regardless of assigned habitat, founders on the North side of Burke Creek (at a lower elevation) were significantly more likely to survive to September than founders of the South side of the creek.

At Upper Truckee East

- 1000 founders from six seed sources (UTE, Taylor Creek, Blackwood, Lighthouse, Regan Al Tahoe, Tallac) were planted in June in four microhabitats: moist shoreline, berm, low beach, high beach
- 73% of one year old founders survived to September

Effects of habitat factors

- Founders at Nevada Beach in the moist shoreline and low beach had significantly greater survivorship, were larger in size, and produced more seed than founders in the high beach.

- In contrast, at UTE founders in the low beach were less likely to survive than those in the high beach. However, this was likely due to very high cover by native lupine in the low beach at that site.
- At UTE, founders in the berm and moist shoreline were significantly more likely to survive to September than those in the low or high beach. Founders in the berm were larger and produced significantly more seed than all other microhabitats.

Effects of initial founder vigor

- Unlike 2003, low vigor founders did not have decreased survivorship or reproductive output at any of the sites. Rather, the higher lake elevation may have increased water availability sufficiently to erase the differences between low and high vigor plants, particularly in the drier habitats. This may have also ameliorated the "stress-induced hardiness" witnessed in 2003 where low vigor plants were actually more likely to reproduce than high vigor plants, especially in drier habitats.

Effect of founder population source

- Two years of un-replicated data from the pilot project and one year of replicated experimental data strongly suggest that founder genotypes (expressed *in situ* as fully functional phenotypes) do not play a significant role in the survival of outplanted seedlings. Therefore, until data to the contrary become available, restoration designs need not incorporate seed source as a variable. In order to retain any unique alleles that may be present in some source populations (see Hipkins and DeWoody 2004), it would be ideal to mix seed from many locations for propagation purposes, but tracking founder seed source is not necessary.

Effect of planting time

- 180 founders were planted in July at UTE in two microhabitats: berm and high beach
- Outplanting late in the growing season (late July) at UTE decreased survivorship and reproductive output. These data strongly suggest that it is optimal to outplant earlier

Effect of founder age

- 45 two-year old container-grown founders were planted in June at UTE. By September, only 51% survived, less than the 73% survival rate of the one-year old founders. These preliminary data suggest that keeping plants in the nursery for more than one year may not afford any benefit in terms of increased survival or reproductive output.

Effect of the water status of founders

- Data results indicate that founders in the moist shoreline experienced less stress than those in the low beach or the high beach, possibly due to differences in soil moisture availability. Mean mid-day water potentials weakly corresponded to survivorship among all sites (mean survivorship decreases as water potentials decrease and water stress increases), suggesting an apparent lack of drought tolerance. However, TYC occupies sandy and exposed microhabitats and it is clear that factors in addition to water status are also influencing survivorship.

Effects of human disturbance

- Fencing helped to reduce impacts from recreational activities among the sites, but three of the enclosures were vandalized during the season. Maintaining fencing throughout subsequent experimental plantings will be important for data collection continuity. Positive identification of individual plants is required for detecting trends in founder survival and reproduction.

Precision seeding

- One month after sowing, very few seedlings had emerged through holes in the planting frames at Upper Truckee East. If all the seedlings were attributed to sown seed, the maximum of 24 seedlings emerging from a total sowing of 1,200 frame holes (each hole received more than one seed) would constitute very low germination and recruitment (2%). These results indicate that sowing TYC seed on the soil surface is an ineffective method for enhancing or creating TYC populations.

Demography of 2003 and 2004 Pilot Populations

- Differential outplanting performance was evident in year two. Survivorship of the 2003 cohort was lowest at Sand Harbor and highest at Avalanche.
- The strong effect of microhabitat on growth and reproduction was evident in year two at all sites with best demographic performance in low beach and poorest performance in high beach. Founders in low beach and moist shoreline were larger, produced more seed, and had greater vegetative reproduction than founders in the high beach.

Founder-cost averaging

- Nearly 90% of the 2003 founders that survived to the end of the first season transitioned into the second season and survived to September, 2004. This 750 established second year-olds represents a return rate of 54% on our initial investment of 2003 founders.
- Outplanting in multiple years at the same site exposed founders to both optimal (2003) and suboptimal (2004) conditions for long-term persistence. The greater first year survivorship at Taylor and Sand Harbor in 2004 compared to 2003 cohort highlights the importance of spreading the risk across years.
- The number of founders from the two cohorts (2003 and 2004) that survived to reproduce is an important indicator of the potential of reintroduced plants to persist and form populations of value to conservation. Survivorship to reproduction in September 2004 was greater than 50% in moist microhabitats (e.g. moist shoreline) and less than 50% in dry microhabitats (e.g. high beach) regardless of site location. This indicates that founders established in moist microhabitats will be more likely to reproduce in subsequent years and more likely to leave behind progeny to maintain the population.

Age-structured outplanting

- Founders at Avalanche and Taylor were more likely to reproduce in the second year (2004) highlights the importance of age structure in a population.

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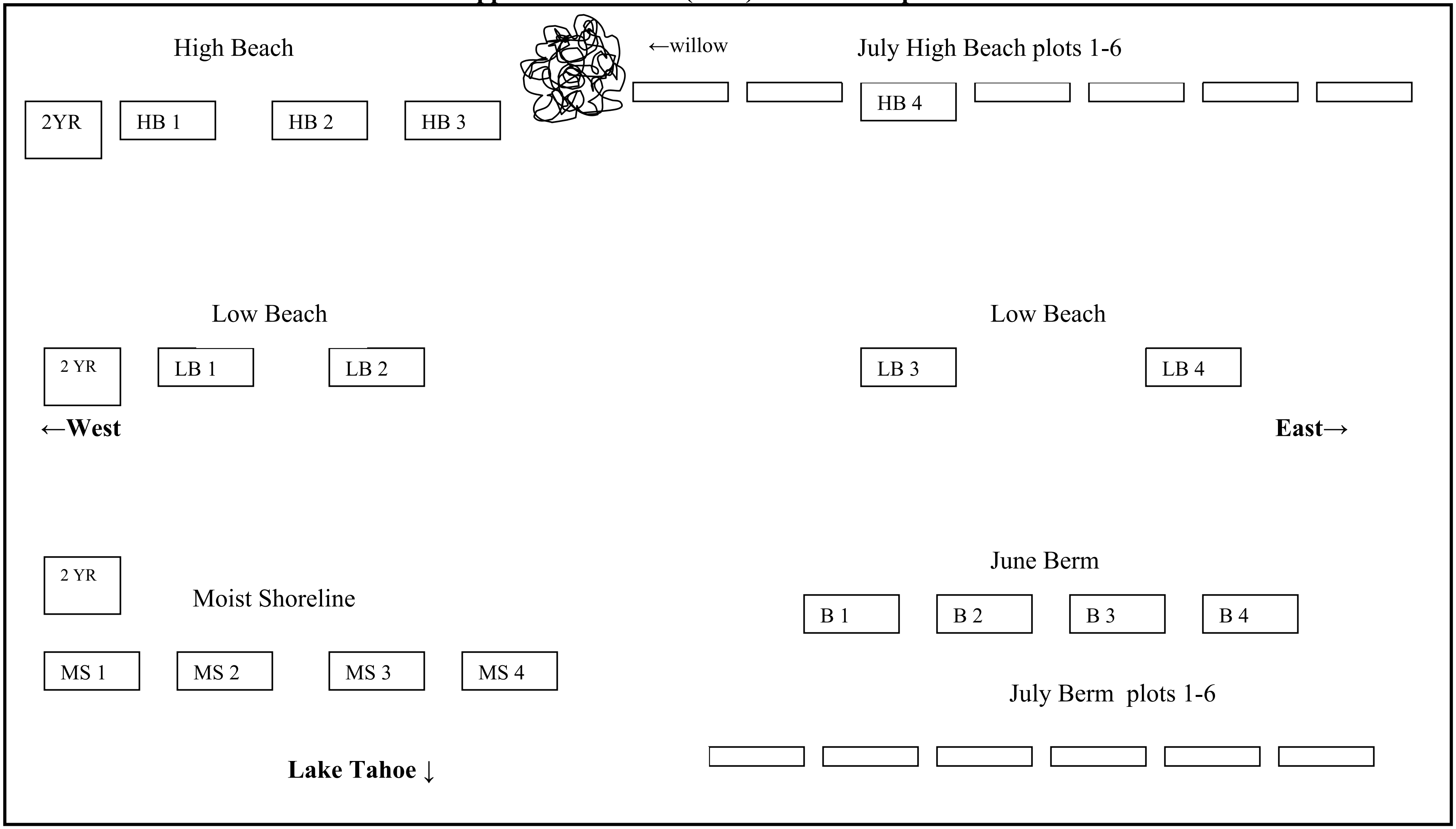
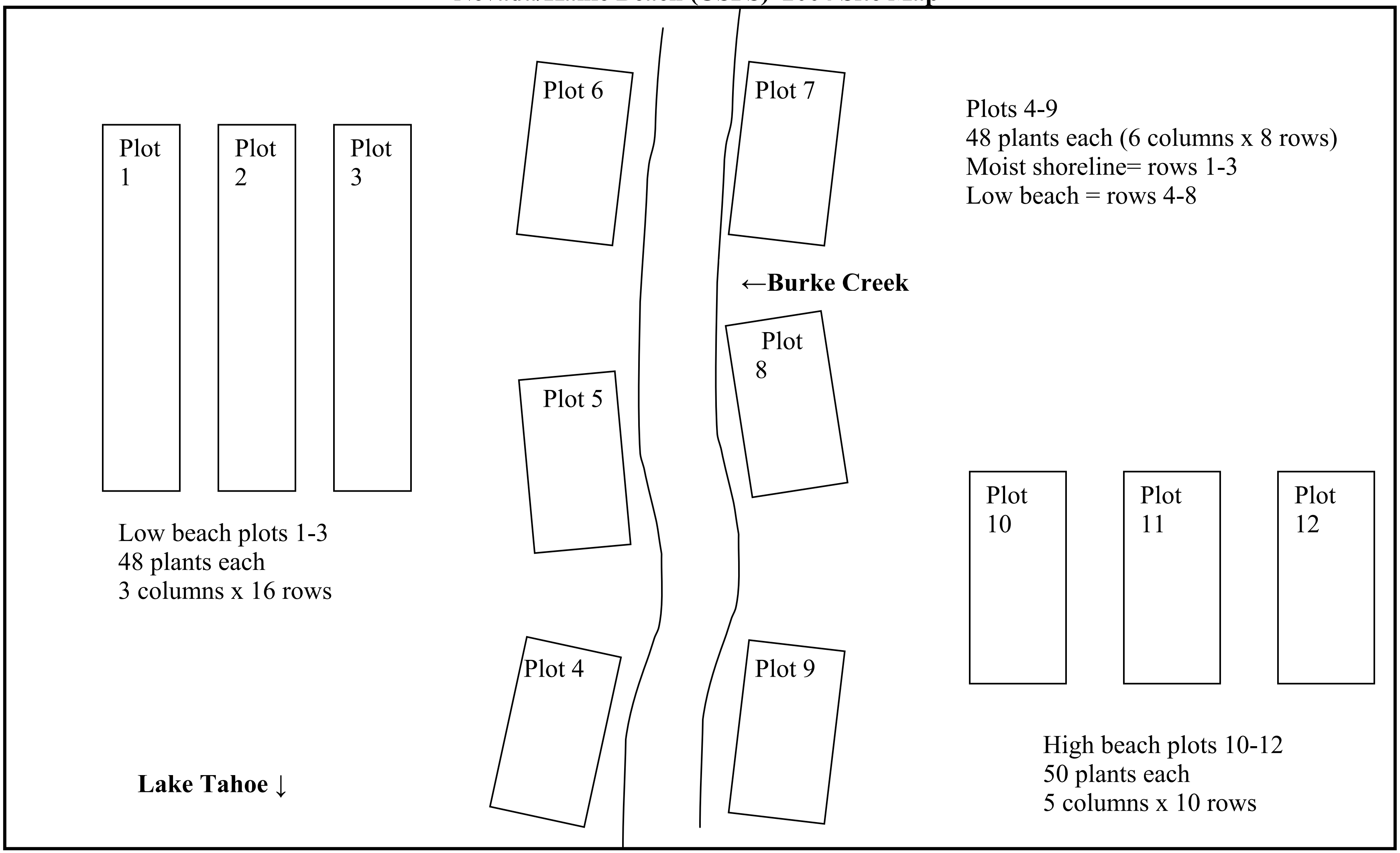
Appendix A Site Maps

Upper Truckee East (CTC) 2004 Site Map



Nevada/Kahle Beach (USFS) 2004 Site Map



Taylor Creek, Baldwin Beach (USFS)
Site Map
x=2004 cohort
o = 2003 cohort

Lake Tahoe ↑

Temporary Enclosure **Taylor Creek→**

Plot # 1 (45 Plants) **Moist Shoreline**
(60 plants from 03 washed away in spring 04)

x x x x x x x x x
x x x x x x x x x
x x x x x x x x x
x x x x x x x x x
x x x x x x x x x

Plot # 2 (440 Plants) **Low Beach**

xoxoxoxoxoxoxoxoxoxoxoxoxoxoxoxoxoxoxoxo
xoxoxoxoxoxoxoxoxoxoxoxoxoxoxoxoxoxoxoxo
xoxoxoxoxoxoxoxoxoxoxoxoxoxoxoxoxoxoxoxo
xoxoxoxoxoxoxoxoxoxoxoxoxoxoxoxoxoxoxoxo
o o o o o o o o o o o o o o o o o o o o **inundated**
o o o o o o o o o o o o o o o o o o o o
←Temporary Water→
xoxoxoxoxoxoxoxoxoxoxoxoxoxoxoxoxoxoxoxo
xoxoxoxoxoxoxoxoxoxoxoxoxoxoxoxoxoxoxoxo
xoxoxoxoxoxoxoxoxoxoxoxoxoxoxoxoxoxoxoxo
Natural TYC Plants on Berm
xoxoxoxoxoxoxoxoxoxoxoxoxoxoxoxoxoxoxoxo
xoxoxoxoxoxoxoxoxoxoxoxoxoxoxoxoxoxoxoxo
xoxoxoxoxoxoxoxoxoxoxoxoxoxoxoxoxoxoxoxo

Plot # 2A (60 Plants) **High Beach**

x x x x x x x x x x x x x x x x x x x x
x x x x x x x x x x x x x x x x x x x x
x x x x x x x x x x x x x x x x x x x x

Walking path between Enclosures

Walking path between Enclosures

Permanent Enclosure **Taylor Creek→**

Plot # 3 (191 Plants) **Dune**

xoxoxoxoxoxoxox
xoxoxoxoxoxoxox
xoxoxoxoxoxoxox
xoxoxoxoxoxoxox
xoxoxoxoxoxoxox
willows xoxoxoxoxoxoxox
xoxoxoxoxoxoxox
xoxoxoxoxoxoxox
xoxoxoxoxoxoxox
xoxoxoxoxoxoxox
xoxoxoxoxoxoxox
xoxoxoxoxoxoxox
o o o o o o inundated
o o o o o o
o o o o o o
o o o o o o

←Back beach lagoon→

Plot # 4 (90 Plants) **Dune Trough**

o o o o o o o o o o o o o o o o o o o o inundated
xoxoxoxoxoxoxoxoxoxoxoxoxoxoxoxox
xoxoxoxoxoxoxoxoxoxoxoxoxoxoxoxox
xoxoxoxoxoxoxoxoxoxoxoxoxoxoxoxox
xoxoxoxoxoxoxoxoxoxoxoxoxoxoxoxox
xoxoxoxoxoxoxoxoxoxoxoxoxoxoxoxox

Plot # 5 (80 Plants) **Meadow**

xoxoxoxoxoxoxoxoxoxo
xoxoxoxoxoxoxoxoxoxo
xoxoxoxoxoxoxoxoxoxo
xoxoxoxoxoxoxoxoxoxo

Sand Harbor (NDSP)
Site Map

x= 2004 cohort
o=2003 cohort
Plot # 3 inundated in 2003

<u>Plot # 1 High beach to moist shoreline</u>

o o x o x o   o o x x x x
o o x o x o   o o x x x x
o o x o x o   o o x x x x
o o x o x o   o o x x x x
o o x o x o   o o x x x x high beach ↑
o o x o x o   o o x x x x
o o x o x o   o o x x x x
o o x o x o   o o x x x x
o o x o x o   o o x x x x
o o x o x o x o o x x x x
o o x o x o x o o x x x x
o o x o x o x x o x x x x
o o x o x o x x o x x x x
o o x o x o x x o x x x x low beach ↑
o o x o x o x x o x x x x moist shoreline ↓
x   x   x x   x x x x
x   x   x x   x x x x
x   x   x x   x x x x
x   x   x x   x x x x
x   x   x x   x x x x

<u>Plot # 2 Low Beach/ Moist Shoreline</u>

x x x x x x x x x   x x
x x x x x x x x x   x x
x x x x x x x x x   x x
x x x x x x x x x   x x
x x x x x x x x x   x x
x x x x x x x x x   x x
x x x x x x x x x   x x
x x x x x x x x x   x x low beach↑
o o o xo   o o x moist shoreline ↓
o xo o o o o o xx x
x x x x o ox o x ox
x x x x o o x o o x
x x x o o   x o o x x
ox x x o o   x o x x
ox x x   x   x x x

Lake Tahoe ↓

Appendix B Monitoring Datasheet

Appendix C Photos

Photo 1. View to the west at Upper Truckee East showing the enclosure, August 2004.

Photo 2. Moist shoreline habitat at Upper Truckee East, August 2004.

Photo 3. Berm formation at Upper Truckee East, August 2004.
The June berm is in the foreground and the July berm is in the background.

Photo 4. Low beach habitat with dense lupine cover at Upper Truckee East, August 2004.

Photo 5. High Beach habitat with sparse vegetation cover at Upper Truckee East, August 2004.

Photo 6. Dune trough habitat at Taylor Creek, July 2003.

Photo 7. Low beach habitat on the north side of Burke Creek at Nevada Beach, August 2004.

Photo 8. Moist shoreline rows (1-5) and low beach (rows 6-8) habitat on the south side of Burke Creek at Nevada Beach, August 2004.

Photo 9. Pressure bomb for measuring plant water potentials (Zephyr Cove, August 2004.

Photo 10. Etiolated plant growing under lupine canopy in the low beach Habitat at Upper Truckee East, July 2004.

Photo 1 View to the west at Upper Truckee East showing the enclosure, August 2004.

Photo 2 Moist shoreline habitat at Upper Truckee East, August 2004.

Photo 3 Berm formation at Upper Truckee East, August 2004. The June berm is in the foreground and the July berm is in the background.

Photo 4 Low beach habitat with dense lupine cover at Upper Truckee East, August 2004.

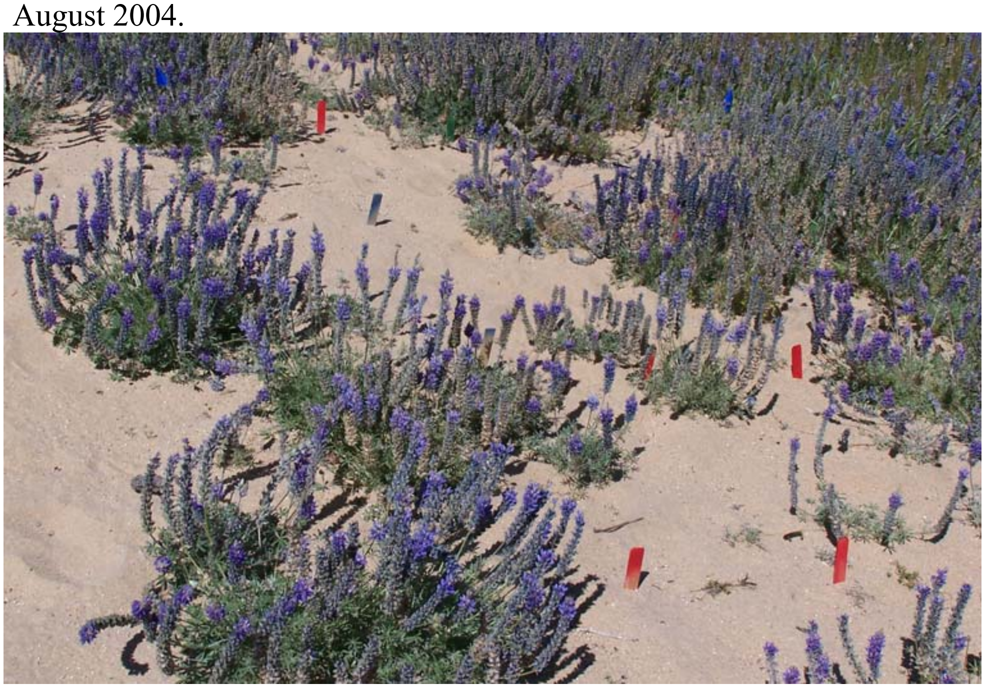


Photo 5 High Beach habitat with sparse vegetation cover at Upper Truckee East, August 2004.

Photo 6 Dune trough habitat at Taylor Creek, July 2003.

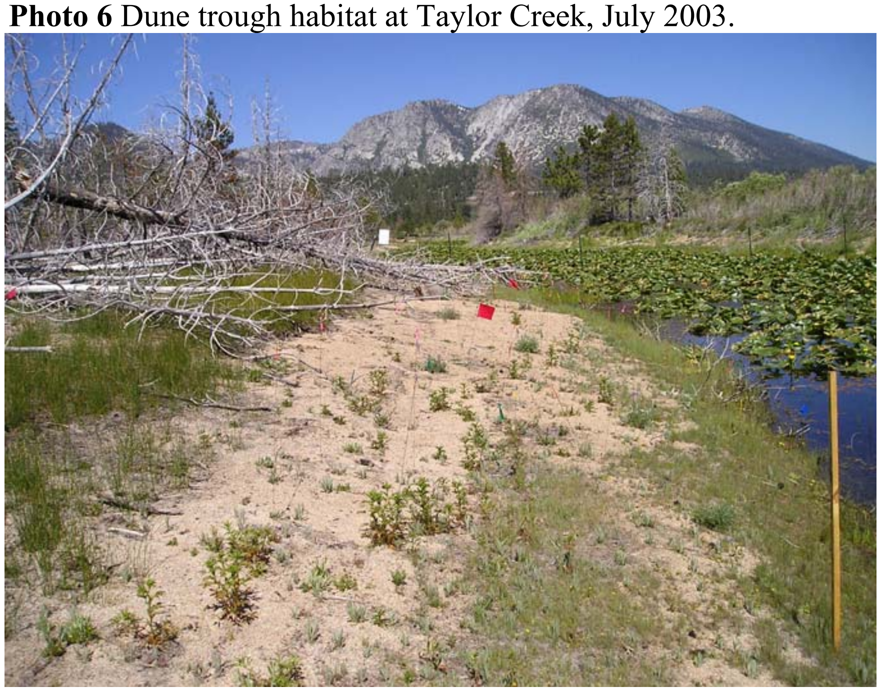


Photo 7 Low beach habitat on the north side of Burke Creek at Nevada Beach, August 2004.

Photo 8 Moist shoreline rows (1-5) and low beach (rows 6-8) habitat on the south side of Burke Creek at Nevada Beach, August 2004.

Photo 9 Pressure bomb for measuring plant water potentials (Zephyr Cove, August 2004.

Photo 10 Etiolated plant growing under lupine canopy in the low beach Habitat at Upper Truckee East, July 2004.