Mitigation Options for

Tahoe Yellow Cress (*Rorippa subumbellata*)

Prepared by:
Alison E. Stanton and Bruce M. Pavlik
BMP Ecosciences
156 South Park
San Francisco, CA 94107

Prepared for:
California Department of Fish and Game
Agreement Number: PO520009
CDFG- North-Central Region
1701 Nimbus Road, Suite A
Rancho Cordova, CA 95670-4599

June 2009

TABLE OF CONTENTS

List of Tables and Figures

1.0 INTRODUCTION

Tahoe yellow cress (*Rorippa subumbellata* Roll.) is a low-growing, perennial species endemic to the shores of Lake Tahoe in California and Nevada. Field surveys have been conducted for TYC since 1978, making the dataset one of the most comprehensive for any endangered plant in the U.S. and possibly the world. The species was listed as endangered by the State of California in 1982 (California Fish and Game Code 2050 *et seq.*) and was state-listed the following year as critically endangered in Nevada (Nevada Revised Statutes [NRS] 527.260 *et seq.*). In 1986, the U.S. Fish and Wildlife Service (USFWS) identified Tahoe yellow cress (TYC) as a category 1 Candidate for listing under the Endangered Species Act of 1973, as amended (ESA), but later downgraded it to a species of concern in 1996. In response to near extinction of the species between 1995 and 1999, TYC was upgraded to a priority 2 Candidate in 1999 (64 FR 57533). A Technical Advisory Group (TAG) was subsequently formed to develop and implement a conservation strategy through a memorandum of understanding / conservation agreement (MOU/CA).The Tahoe yellow cress Conservation Strategy (CS) (Pavlik *et. al* 2002) provides the basic framework for the recovery of the species.

An analysis of the long-term dataset contained in the CS determined that the number of TYC occurrences around the lake correlates directly with fluctuating lake levels. Wide expanses of beach are available for colonization and the number of occupied sites is generally high when the lake is low (with an elevation between 6,220-6,224 feet Lake Tahoe Datum [LTD]). During high water periods (greater than 6,226 ft LTD), less habitat is available, pressure from recreation intensifies in the remaining habitat, and the number of occupied sites declines. The potential for sustained high water levels and increased recreation pressure continue to pose a threat to the long-term, persistence of Tahoe yellow cress.

The overall intent of the CS is to preclude the need to list TYC under ESA through promoting conditions that favor a positive metapopulation dynamic. TYC follows the general dynamics of a "mainland –island" metapopulation model. This model of metapopulation dynamics refers to spatio-temporal changes in distribution and abundance where "mainland" subpopulations persist over long periods of time while other "island" subpopulations come and go through the processes of local colonization and extirpation. Thus, the species can persist in sandy beach habitat around Lake Tahoe despite periodic high water levels and human-related impacts.

The TYC conservation strategy adopts this metapopulation model as a conceptual framework and includes goals that promote conditions for reestablishing a positive dynamic (colonizations > extirpations) for self-maintenance of the species into the indefinite future. An adaptive management framework was developed to prioritize research with a set of Key Management Questions (KMQ), structure information flow, and provide a tool for developing and evaluating management actions. The following entities have committed to the implementation of the conservation strategy: Tahoe Regional Planning Agency, U.S. Fish & Wildlife Service, U.S. Forest Service, Nevada Division of Forestry, Nevada Division of State Lands, Nevada Division of State Parks, Nevada Natural Heritage Program, California State Lands Commission, California

Department of Fish & Game, California Department of Parks & Recreation, California Tahoe Conservancy, Tahoe Lakefront Owners' Association, and League to Save Lake Tahoe.

Adoption of the CS launched the adaptive management phase of TYC. A one-year pilot study in 2003 primarily addressed objectives on techniques for nursery propagation, fencing, outplanting, and monitoring and demonstrated that TYC was a "cooperative" species, amenable to experimentation and responsive to critical variables identified by the KMQ framework. Replicated experiments designed to address specific KMQs and the information needs in the adaptive management process were subsequently installed beginning in 2004. To date, over 8,200 container-grown plants (founders) have been installed at 14 sites around the lake. A series of six technical reports describe these recent research activities (Pavlik and O'Leary 2002, Pavlik *et al.* 2002b, Pavlik and Stanton 2004, 2005, 2006, 2007). In addition, eight Tahoe yellow cress annual reports have been completed since 2001 that provide a record of all the conservation activities related to Tahoe yellow cress. These are available on the Nevada Natural Heritage website at http://heritage.nv.gov/vlibtyc.htm.

Experimental reintroductions in different microhabitats and in years with different lake levels allowed us to evaluate the role of source population genetics, depth to water table, and inundation in population restoration. Survivors in suitable habitats produced more than 1.5 million seeds and nearly 10,000 asexual plantlets (Stanton and Pavlik 2007). Such tangible benefit to the species prompted the U.S. Fish and Wildlife Service to downgrade TYC in 2005 to a priority 8 Candidate because of "continued commitments to conservation demonstrated by regulatory and land management agencies participating in the Conservation Strategy" (69 FR 77167).

The experimental reintroductions have paved the way for investigating mitigation options for unavoidable impacts of construction or other development projects on the shores of Lake Tahoe. Translocation is one possible tool. Translocation involves moving established plants in the field from one location to another. It has been used as mitigation for the disruption of sensitive species habitat and as a salvage measure to preserve individuals when habitat is destroyed. In the past, many translocation projects have lacked a rigorous experimental component and adequate monitoring. In addition, translocation projects are often undertaken with little or no knowledge of the horticultural requirements or genetic architecture of the species.

However, translocation could be an effective mitigation measure for TYC for three reasons. First, the horticultural requirements of the species are known. Although germination trials in the lab yielded poor results, over 10,000 plants have been successfully propagated in the greenhouse. Second, the National Forest Genetic Electrophoresis Laboratory (NFGEL) used allozymes to assess genetic variation and concluded there was little genetic variation (Saich and Hipkins 2000, DeWoody and Hipkins 2004, DeWoody and Hipkins 2006) and therefore, genetic contamination through outplanting efforts may not be a concern. Finally, the research program has included demographic monitoring and physiological monitoring of the water status of outplanted individuals and has identified the optimal techniques, plant characteristics, habitat conditions, and logistical factors that optimize the chances for successful restoration of the species at Lake Tahoe. Given the unique circumstances of the robust research program and the adaptive management framework, an informal consultation between CDFG and the USFWS regarding the disturbance of natural populations of a candidate species resulted in a decision to support translocation research with Section 6 funds. CDFG approved a sole source contract to BMP Ecosciences in Agreement Number PO520009 to support translocation work from 2006 to 2008.

The potential use of translocation as a mitigation tool is a critical management concern in light of many proposed Lake Tahoe Environmental Improvement Projects (EIP) and the newly approved Shorezone Plan for the region. Reversing a moratorium on most new pier construction that has been in place for more than 20 years, the new Shorezone Plan allows 138 new piers, 6 boat ramps, and 235 boat slips on the shores of Lake Tahoe. Although the plan is likely to be in litigation for some time, the availability of new mitigation and restoration tools would be a valuable asset in reducing impacts to TYC if and when new development occurs. Likewise, the basin-wide EIP targets many of the creek mouths that support core TYC populations including the Upper Truckee River, Blackwood Creek, Ward Creek, and Tallac Creek for SEZ restoration and other projects that could impact the shorezone environment. In instances on both private and public lands where avoidance of naturally occurring TYC plants is not possible it will be crucial to know the effectiveness of moving plants within or between sites.

2.0 Objectives

The ability to successfully manage TYC has been limited by our understanding of the biology of the species. Reintroduction and translocation experiments present the greatest opportunity for increasing our knowledge of TYC. This project is part of a phased adaptive management program to increase the sustainability of TYC populations and meet the recovery criteria set forth in the CS, specifically, to address goal 4 of the CS to "Conduct research that directly supports management and restoration".

The objective of this project is to test translocation as a mitigation option for unavoidable impacts from construction or other development projects on the shores of Lake Tahoe. The translocation project has been designed to complement the experimental reintroductions and to benefit the species by increasing the number of methods available that may increase TYC persistence and reduce any trend toward extinction. Because as many as 50% of the occupied sites in any given year are on private lands, research that supports the development of more management options will also help engender the support and stewardship of private landowners.

3.0 Methods

3.1 Translocation

TYC plants that were selected for translocation were either experimental plants that had been container-grown in a nursery and outplanted as part of a previous reintroduction experiment or they could be naturally occurring. While the previously outplanted container-grown plants could be considered " experimental" informally, state and federal sensitive plant regulations do not address such distinctions. The difference is discussed below in section 3.3 Regulatory Compliance.

To begin the translocation at a donor site, first the canopy area, measured as a length and a width, was recorded for each donor plant along with the phenology. Next, a "sharp-shooter" shovel was inserted into the sand several centimeters away from the above-ground canopy. Care was taken to cut outside of the zone of the perceived rootmass . The researcher then grasped the above ground cluster of stems and plant canopy and the rootmass was slowly extracted with a rocking motion of the shovel to capture as much root structure as possible and minimize damage. Very little soil clung to the roots once exposed because of the sandy nature of the substrate. The plant and bare rootmass was placed in a moist plastic ziplock bag, labeled and kept in the shade. After the last plant was extracted from the donor site, plants were immediately transported to the receptor site.

Each planting area at the receptor site was pre-watered to allow digging of a hole approximately one foot deep to accommodate the extended rootmass. Each plant was carefully secured in the ground with sand before more water was applied. All plantings were hand watered for three days following the translocation. The demographic performance of all plants, including phenology and canopy size was monitored on a monthly basis through September.

3.2 Plant Propagation

Beginning in 2002, TYC has been propagated on an annual basis at the Nevada Division of Forestry (NDF) Washoe nursery at an elevation of 5,000 ft in Washoe Valley, Nevada. Seed were collected from multiple sites in September of the year prior to propagation following guidelines from the Center for Plant Conservation that are designed to ensure representative samples and maximize genetic diversity. Seed were kept segregated by collection site and stored in manila envelopes at room temperature. In 2002- 2005, seed were sown in the fall the year of collection, but beginning in 2006, seed were sown in January for planting the same year. A pinch of seed was top- sown in plastic supercells with standard greenhouse soil-less potting mix. A light layer of Lake Tahoe beach sand or vermiculite was sprinkled on the surface to cover the seeds.

All propagated seedlings were maintained in a secured area in a greenhouse with top-spray irrigation and light fertilizer mix. No herbicide, pesticides or fungicides were used. The soil-less potting mix was free from any known contaminants and plants were individually inspected and hand-sorted according to seed lot and vigor prior to leaving the greenhouse. Only high quality plants were transported and used in outplantings. The USFS primarily grows woody shrubs and conifers for federal and state restoration projects and did not propagate any close relatives of *Rorippa subumbellata*.

3.3 Regulatory Compliance

When the Adaptive Management Working Group (AMWG) first contemplated the feasibility of n translocation experiment, several regulatory compliance issues came up, some of them unique to the Lake Tahoe basin. The Tahoe Regional Planning Agency (TRPA) Code of Ordinances (Chapter 75.2) prohibits all projects or activities that are likely to "harm, destroy, or otherwise jeopardize sensitive plants or their habitat" unless they can "fully mitigate their significant adverse effects". The environmental threshold standard for sensitive plants (V-3) applies a "non-degradation" standard to sensitive species but it is not clear if the standard applies to individual plants or to the minimum number of population sites (26) specified by the V-3 Threshold. The main standard in the permitting process has been avoidance of TYC plants and habitat and in the absence of other approved mitigation measures such as outplanting or translocation, the Code has been interpreted to mean that all TYC plants are protected and cannot be harmed in any way. The AMWG decided that the regulations applied only to natural plants and that container-grown plants that were installed in any of the experimental reintroductions begging in 2003 could be informally considered as "experimental". Therefore, the AMWG only approved translocation of experimental container-grown individuals of TYC.

Pilot-scale translocations of plants from the 2003 to 2005 experimental cohorts were approved in both 2005 and 2006. However, the level of Lake Tahoe in 2006 rose to the legal limit imposed by federal court degree to 6,229.1 ft LTD, greatly reducing the amount of habitat for TYC and the number of occupied sites around the lake. All past experimental cohorts were inundated so there were no experimental TYC available for the translocation experiment in 2007 when the CDFG-funded study on mitigation options was scheduled to begin. In addition, the 2006 translocation proved successful at one site but the results indicated that one-year-old outplanted individuals with limited root development were not likely to provide an appropriate surrogate for naturally occurring plants that have more extensively developed above and below ground root systems (see section 4.1). Therefore, the AMWG approved translocation of naturally occurring TYC, but imposed a limit of 10% of the naturally occurring stems that emerged at a site in 2007 that could be available for the translocation experiment.

The Forest Service dissented from the AMWG and only supported the translocation of experimental container-grown individuals and did not support the translocation of naturally occurring TYC on Forest Service land. The opinion of the Forest Service was that translocation of natural populations should only be implemented as a last resort tool for populations that are going to be impacted by approved project implementation. This opinion was not shared by other members of the AMWG. In addition, the take of naturally occurring TYC would require a permit from the Regional Forester according to regulation FSH 2609.25 in the Botanical Program Management Handbook under the guidelines for sensitive species collection and the staff at the Lake Tahoe Basin Management Unit did not want to pursue that option. Therefore translocation of naturally occurring TYC in 2007 and 2008 was limited to private property in California and Nevada and on state lands in California.

3.3 Experimental Design

A project with unavoidable impacts to TYC would result in the need to 1) move the plants out of the way within the same microhabitat at the same site (i.e from high beach to high beach), 2) move the plants upslope at the site to a different habitat (i.e low beach to high beach) or 3) move the plants to a similar microhabitat at another site. We would hypothesize that the first option provides the greatest chance of successful translocation since the distance moved is small and the substrate and microclimate would stay the same. The second option could dramatically reduce survivorship if the upslope receptor microhabitat is considerably drier than the donor microhabitat. Plant performance under the third option could be equal to option one if the conditions between the donor and receptor sites were similar enough. A fourth mitigation option could be to avoid translocation and simply outplant container-grown TYC.

An ideal experimental translocation design would therefore evaluate the effects of site, microhabitat, lake elevation, translocation timing (seasonality), subsequent watering regime, and transplant size in a fully replicated framework over a period of time. However, many of these factors were addressed in the experimental reintroductions of container-grown plants in 2003 through 2006 that provided a wealth of information on the horticultural and habitat requirements of the species. Therefore, the experimental design for 2007 to 2009 was developed to test the question: Do the methods of translocation (of naturally occurring TYC) and outplanting (of container-grown TYC) result in the same demographic performance (i.e survival and reproduction rates) in a given microhabitat? If the results were not significantly different, then it would be appropriate to apply the lessons learned from the reintroduction efforts over the last four years regarding the effects of microhabitat, site, and lake elevation to translocation and it would not be necessary to test these factors using naturally occurring plants. Planting container-grown plants also provides a means to offset any loss of naturally occurring TYC from the translocation experiments.

The experiments utilized a paired-design of one container-grown plant for each naturally occurring translocated plant, with 50 replicate pairs per site. For each pair, a naturally occurring plant from the donor location was translocated to the receptor location and a container-grown plant was outplanted one half meter away at the same elevation. An analysis of the variances in the data from the 2006 pilot translocation and the 2006 outplanting determined that the 50 container-grown plants used in blocks in past outplantings represented a statistically valid sample size. The null hypothesis is that translocation of naturally occurring TYC and outplanting of container-grown TYC result in the same rates of survival and reproduction.

3.4 Site Selection and Installation

2005 and 2006 pilot-scale translocations

In 2005, the AMWG approved a pilot-scale translocation within the permanent enclosure at Baldwin Beach (USFS) at the mouth of Taylor Creek. This site consistently supports large numbers of TYC in both low and high water level years. Container-grown plants were installed in both temporary fencing and the permanent enclosure in 2003 and 2004. Sufficient space was available in the permanent enclosure in 2005 to allow for the translocation of surviving founders from the 2003 and 2004 cohorts.

On June 24, 2005, a total of 56 one and two-year old founders were extracted and moved approximately 100m (300 ft) to the east within the enclosure. The plants were installed in 4 replicated blocks with half meter spacing between individuals. Each replicated block consisted of two treatments: amended with soil-less potting mix, and no potting mix. Each block contained 7 individuals for a total of 28 individuals per treatment. Each planting area was pre-watered to allow digging of a hole approximately one foot deep in order to accommodate the rootmass without bending. For the amendment treatment, approximately 1 gallon of potting mix was mixed in the hole with the sandy substrate before planting. The seven individuals in a block were laid out in a clumped design and each plant marked with a wire flag. Plots were monitored at two, four, and eight weeks after planting.

In 2006, the translocation was conducted using two donor and two receptor sites. At Zephyr Cove (USFS), 38 founders from the 2003 cohort were translocated from high beach habitat (6,228.9-6,229.8 ft) to similar habitat within the permanent enclosure at Baldwin Beach (USFS) at the mouth of Tallac Creek (6,229.2-6,230.9 ft). The high beach plot at Zephyr Cove had been enclosed with permanent fencing since the installation in 2003, but in early June it was evident that most of the site would be inundated by the rising lake. The USFS removed the fence the day before the translocation to facilitate what was essentially a salvage operation. The translocation was conducted simultaneously with the experimental reintroduction of container-grown plants to Tallac Creek on June 8th, 2005. The site at Tallac Creek has supported a moderate number of plants in all lake level years.

The only other site in 2006 that supported plants from a previous experimental cohort was Pope Beach (USFS). A total of 30 founders from the 2005 cohort had emerged by early June and although the high beach plot was not going to be inundated, the founders were translocated from the high beach at Pope (6,230-6,230.8 ft) to the permanent enclosure at Taylor Creek (6,230.2-6,231 ft). The translocation was conducted simultaneously with the experimental reintroduction of container-grown plants to Taylor Creek on June 9th, 2005. The site at Pope had not supported plants prior to the outplanting in 2005.

Experimental translocations

The experimental translocations in 2007 and 2008 utilized a paired-design of one container-grown plant for each naturally occurring translocated plant, with 50 replicate pairs per site. For each pair, a naturally occurring plant from the donor location was translocated to the receptor location and a container-grown plant was outplanted one half meter away at the same elevation.

2007 Experimental translocation

The 2007 experimental translocation took place on August 1-2 at two sites: within the permanent enclosure at the mouth of the Upper Truckee River (CTC), and on private property at the mouth of Blackwood Creek in Placer County, CA. As in past experiments, the plots were watered for three days after outplanting/translocation and monitored at 2, 4, and 8 weeks.

All past experimental plantings were conducted around early to mid-June when the lake is at the highest level for the season. In 2007, implementation was delayed until August because the AMWG was debating the terms of using naturally occurring plants in the experiment (see section 3.3) and because of obstacles in site selection. The original experimental design had a more robust experimental sample size of 7 sites, including three USFS enclosures (Taylor Creek, Baldwin Beach, Meeks Bay), and two private sites at Edgewood Golf Course (Stateline, NV) and Ward Creek (Placer County, CA). However, the USFS objected to the translocation of naturally occurring TYC on National Forest Lands (see section 3.3) so those sites were eliminated from consideration. Efforts to install the experiment at two of tthe private sites were delayed until it was too late in the season to proceed.

The permanent enclosure at the mouth of the Upper Truckee River Plants supports the largest concentration of TYC. Hundreds to tens of thousands of stems have been counted in the annual survey at the site since 1979. For the translocation, plants were moved from the west end of the beach near the river mouth to the east edge of the enclosure where plants had been previously outplanted in 2004 and 2005. Both cohorts were inundated in 2006 and few TYC were present in the area at the time on the translocation. The 100 plants that were part of the translocation experiment were place in pairs from .5 to 1.0 feet above the level of the lake along a strip of the low beach habitat.

The beach on the south end of Blackwood Creek is managed for public access through a public easement granted by Placer County. The north side of the creek has limited public access and is considered private property. For the translocation, plants were moved from the south to the north side of the creek on August 1. The 100 plants that were part of the translocation experiment were place in pairs in the mosaic of variable habitat that includes beach, back beach depression, and cobble river mouth. The North Blackwood homeowner was very cooperative and pleased with the project. The lake level was 6,227.0 ft LTD, approximately 0.6 ft lower than the peak elevation for the season reached at the beginning of June.

2008 Experimental translocation

The AMWG set new site selection criteria for the 2008 experiment. Eligible sites required a 2007 stem count greater than 400 stems. The threshold of 400 stems was based on the minimum viable population (MVP) analysis contained in the Conservation Strategy that identified a population size of 300 stems as affording a 75% chance of persistence over 20 years. Since a total of 50 individuals were proposed for translocation at each site, the threshold value was set higher than 300 in provide a buffer and ensure a final stem count greater than 300.

Of the 30 sites that were occupied in 2007, seven had stem counts greater than 400, all of them Core or High priority: Ward Creek, Blackwood Creek, Eagle Creek/Avalanche, Taylor Creek, UTE, Edgewood, and Nevada Beach. Sites were eliminated for various reasons. Some of the owners at Ward Creek were again receptive to the idea (they were approached in 2007), but apparently at least one member of the trust was not supportive and no permission was granted. At Blackwood, the owners were very supportive of the project but the north side of the creek only supported 305 stems and was instead used for the experimental test of outplant timing. The south side of the creek is operated as public property below high water, so fencing would have been required, but it was not apparent how that could be accomplished. Eagle Creek/Avalanche was considered too small and variable. Nevada and Taylor were withdrawn because the USFS did not support the translocation experiment of naturally occurring individuals on FS lands, citing Regional direction (FSH 2609.25.10.15.20). Consequently only two sites were selected; California Tahoe Conservancy (CTC) again granted permission to utilize Upper Truckee East (UTE) and Edgewood Golf Course gave permission to utilize the beach adjacent to the golf course.

The 2008 experiment utilized the same paired-design from 2007 with one container-grown plant for each naturally occurring translocated plant, with 50 replicate pairs per site. The translocation took place at Upper Truckee East on June 17th. At Edgewood Golf Course, which is private property in Nevada, the translocation took place on June 18th. The lake level was 6,225.5ft LTD, the peak for the season. As in past experiments, the plots were watered for three days after outplanting/translocation and monitored at 2, 4, and 8 weeks.

At Edgewood, donor plants were removed from the eroded pit just north of Edgewood Creek that formed as a result of a storm in January 2006. The receptor area was about 150m down the beach just south of the creek mouth in a location that has historically supported TYC, although TYC has not been observed in the area since 2005. The 100 plants that were part of the translocation experiment were place in pairs in uniform habitat about 2 feet above the level of the lake and only several feet from the green of the last hole.

At UTE, donor plants were taken from two locations; 18 plants were moved from outside the enclosure at Harootunian Beach at the east end of the site near where Trout Creek breeched the dune in 2006; donor plants were also moved from the west end of the beach near the Upper Truckee River from an area that supported thousands of plants. The receptor location was at the east edge of the enclosure where the 2007 translocation had occurred. Only 6 plants from the 2007 were apparent in June and the area was mostly clear of naturally occurring TYC at planting time and therefore the 100 plants that were part of the translocation experiment were place in pairs in that same strip of habitat from .5 to 1.0 feet above the level of the lake.

4.0 RESULTS

4.1 Pilot translocations

The 2005 pilot translocation was compromised when the wire flags marking the transplants were removed by vandals for a second time in August. It was difficult to positively identify and remark the individuals because of the recruitment of natural seedlings subsequent to the installation. Uncertainty over the identification of specific plants lowered the total number of translocations that could be evaluated from the original 56 to only 32.

A total of 77% of the transplants apparently had survived until July 11, two weeks after translocation. By the time of the four week monitoring, the flags had been removed but it was still possible to relocate them. Total survivorship had risen to 87.5%, although some of the increase could be attributed to natural seedling recruitment. By the end of August, the flags had been removed again and total survivorship was estimated at 84%, or 27 of the identifiable 32 translocations. Despite the limited dataset, the apparent high survivorship indicated that it is possible to move plants within a site and that pursuing translocation as a potential mitigation strategy was warranted.

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

For the 2006 pilot translocation, a total of 57% of the transplants at both sites survived until September the first year. However, translocated founders performed much better at the Tallac receptor site than at the Taylor Creek receptor site. At Tallac, mean survivorship and reproduction of the three-year-old founders from Zephyr Cove were much greater than the one-year-old founders transplanted from Pope to Taylor (Figure 1). Overall mean canopy size at Tallac was 120 cm^2 and the average reproductive plant output 447 seeds, for an estimated total seed production of 10,132 seeds (Table 1). At Taylor, the few surviving plants were very small (12 cm^2) and only 1 individual survived to fruit in September.

Table 1. Survivorship and reproductive output of the 2006 translocation cohort at two sites, September, 2006. (NA= not available)

Site and Block	# transplanted	Survivorship (% of transplants)	Reproduction (% of surviving)	Total plantlet production (#/block)	Mean canopy Area (cm2/plant)	Mean seed output (# per plant)	Total seed production (# per cohort)
Tallac							
Block 1	12	42	60	0	114	561	
Block 2	12	83	90	0	101	337	
Block 3	14	100	100	53	144	442	
							10,132
Taylor							
Block1	10	20	10	0	NA	10	
Block 2	10	70	0	0	12	0	
Block 3	10	10	0	0	NA	0	
							10

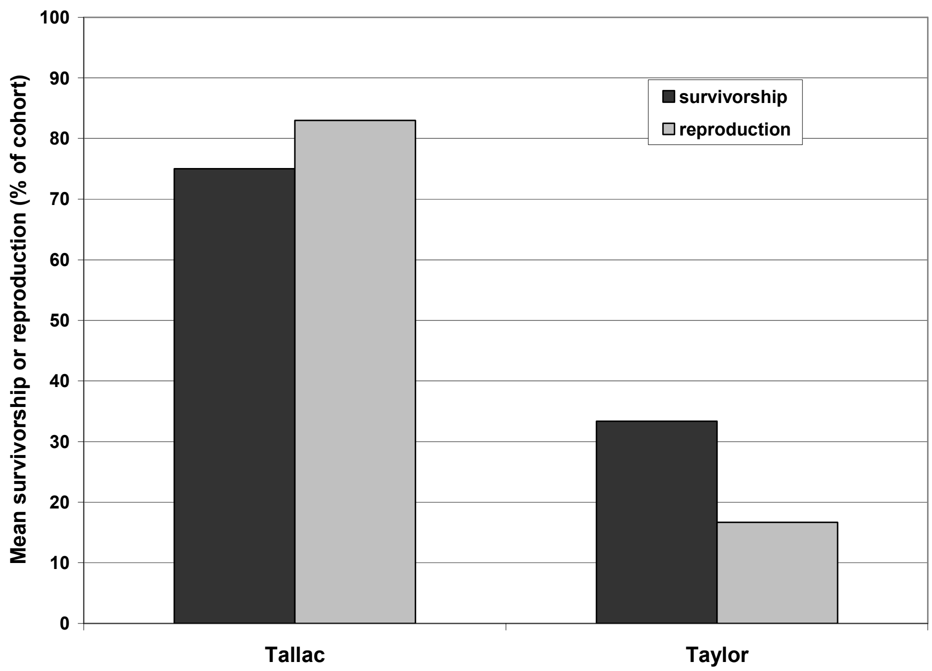

Figure 1. Mean survivorship and reproduction of transplanted founders at two sites in September, 2006.

The 30 plants from the 2005 cohort that were translocated to Taylor were removed from the high beach habitat at Pope Beach. The elevation of that plot was greater than 6,229.1 ft and it was never inundated by the lake. The 2006 cohort was planted on the half meter in between what had been the 2005 cohort to determine if any plants that were dug up re-sprouted. By August, a total of 15 plants (50%) had re-sprouted in their former locations next to the 2005 wooden stakes. The re-sprouted plants actually out-performed founders in the adjacent 2006 cohort. The mean canopy size (131 cm2) and seed output per plant (584 seeds) were greater in the re-sprouts than in the 2006 founders in any plot except the meadow plots at Taylor Creek. Ten of the 15 re-sprouts (67%) survived to reproduce by September, adding an estimated 5,836 seeds to the site. Apparently the removal of the canopy and a great majority of the root system left behind a sufficient amount of well-developed roots that the plants were able to access water for growth.

The individuals that were translocated from the high beach at Zephyr Cover were submerged by the rising lake and so it was not possible to make a comparison of re-sprouting capacity with Pope Beach. Still, the 50% re-sprout rate at Pope suggests that it may be feasible to test translocation on naturally occurring plants. While only 10 of the 30 plants (30%) that were moved from Pope to Taylor survived to September, the re-sprouting of 15 plants at Pope means that the net loss of plants was only 5 plants (15%). The high beach at Taylor was not optimal habitat and the loss would have been even less had the translocation been conducted at more mesic site, such as Tallac. The AMWG will need to discuss if 15% is an acceptable risk level for the benefit of learning more about potential mitigation options.

Prior to translocation, the initial size of all emerging individuals was measured at the Zephyr Cove and Pope Beach donor sites. A regression analysis of initial plant canopy size in June against final plant canopy size in September revealed a very weak relationship, indicating that initial vigor did not play a strong role in the performance of translocated founders (Figure 2). The mean initial canopy size of founders from Zephyr Cove was virtually equal to the mean canopy size at Pope, 23 and 24 cm^2per plant, respectively. Although the founders from Zephyr Cove were two years older than the founders from Pope, the similar initial size of the cohorts and the weak relationship with final plant canopy size suggests that age did not play a strong role in the outcome either. However, one would expect that a three-year-old founder might have a greater underground root mass early in the season than a one-year-old and so any differences in overall vigor related to age would not necessarily be reflected in plant canopy size.

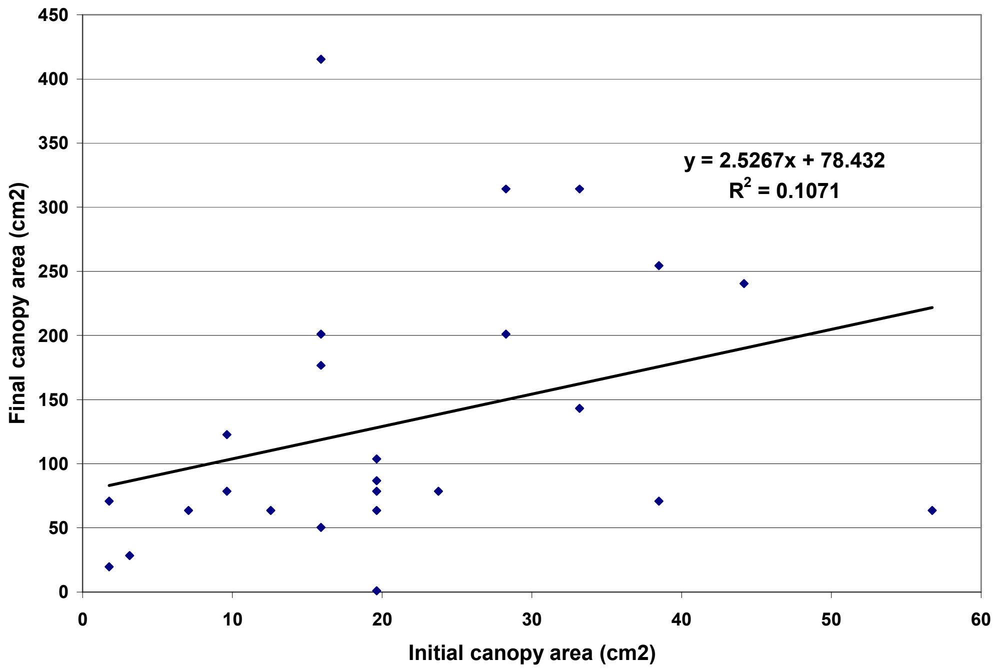

Figure 2. Initial plant canopy size in June and final plant canopy size in September of translocated founders at Tallac, 2006.

Microtopographical differences in site elevation were likely responsible for the differential performance of translocated founders at the Tallac and Taylor Creek receptor sites. When the entire habitat is considered, the high beach at Tallac (6,229.2-6,230.9 ft) occurred at roughly the same elevation as Taylor (6,230.2-6,231ft). However, the translocation blocks at Tallac (with the exception of block 3) were actually subjected to some inundation and were just above high lake level (6,229.2-6,229.5 ft). Therefore, the high beach blocks at Taylor were essentially one foot higher above the lake than the Tallac plots. The effects of elevation on survival are evident in the differential survival between the blocks at both sites. At Tallac, survivorship was greatly reduced in block 3 at the eastern end of the enclosure (Table 1). This plot was about one half foot higher than the rest of the high beach translocation habitat. At Taylor, a smooth elevation gradient did not exist from east to west and the central block (#2) was actually lower then the blocks at either end of the enclosure. Consequently, there was greater survivorship of founders in block 2 and it was the only location where one individual managed to reproduce.

Differences in performance between Tallac and Taylor may also be explained by the measured xylem water potentials. Predawn water potentials were very similar early in the season in June, but in August, the mean water potential of founders at Tallac (-1.9 bars) was significantly higher than those at Taylor (-3.6 bars), indicating that plants at Taylor were experiencing greater baseline water stress in the middle of the growing season (data not shown). The difference between sites disappeared by September. Mean midday water potentials were significantly higher at Tallac than Taylor from June through August, indicating that the stress differential was maintained for most of the growing season (Figure 3).

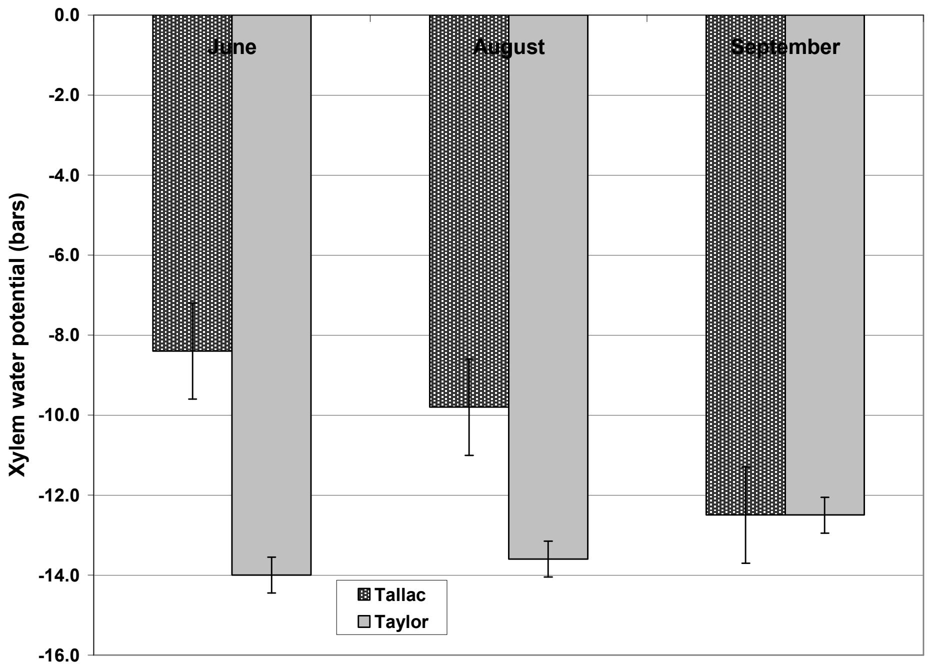

Figure 3. Mean midday water potentials of translocated founders in the high beach at Tallac and Taylor in 2006. Bars indicate ± 1 SE.

Finally, the demographic performance of translocated founders was not significantly different than that of outplanted container-grown founders. At Tallac, mean survivorship was 77 and 75% for outplanted and translocated founders, respectively, while mean reproduction was 80 and 83%. The mean canopy size (127 and 120 cm^2) and seed output (477 and 446 seeds per plant) of surviving individuals from both methods (outplanted and translocated founders, respectively) was also very similar. At Taylor, the poor demographic performance of outplanted founders was also mirrored by poor performance of the translocated founders. Only 4% of the outplanted founders and only 3% of the translocated founders survived to reproduce in September. Consequently, the small number of reproducing survivors prevented any analysis of mean canopy size or seed output at this site. Taken together, the limited data from these two sites suggest that the methods of outplanting and translocation can produce similar results, but further testing with greater numbers of plants and more sites will be required.

The second year performance of the 2006 followed the pattern of the first year and the performance of translocated and container-grown founders was again very similar. Mean survivorship in September of translocants and container-grown founders at Tallac was 69 and 77%, respectively (Table 2). At Taylor Creek, 20% of the translocants from Pope survived and second year survivorship of the container-grown plants was 14%. Plant size was rather small, regardless of source and consequently, seed production was moderate. At Pope Beach, the individuals that had re-sprouted in 2006 had a much greater mean seed output than either the translocated or the container-grown plants and by September

2007, 5 more founders appeared to re-sprout and occupy the outplanting spot near the wooden stake.

Table 2. Second year performance of the 2006 container-grown and translocation cohorts at Tallac and Taylor Creek September 2007.

Site	Source	N	Canopy area (cm^2)	Seed output (# per plant)	Survivorship (%)	Survivorship to reproduction (%)	Total seed production (# per site)
Tallac	container	150	50.5	297.6	76.7	38.7	12,201
Tallac	translocation	36	40.4	344.4	69.4	33.3	1,722
Taylor	container	100	105.0	360.4	14.0	12.0	3,965
Taylor	translocation	30	85.1	254.1	20.0	20.0	1,271
Pope	translocation re-sprouts*	30	168.1	586.9	66.7*	56.7*	9,997

* 15 plants from 2005 cohort reappeared in 2006, 20 were present in 2007 with 17 in fruit

Mean second year survivorship to reproduction in 2007 (the proportion of planted/translocated founders that were in fruit in September) declined by almost half at Tallac when compared to 2006 for both translocants and container-grown founders (Figure 4). In contrast, mean survivorship to reproduction at Taylor increased in 2007.

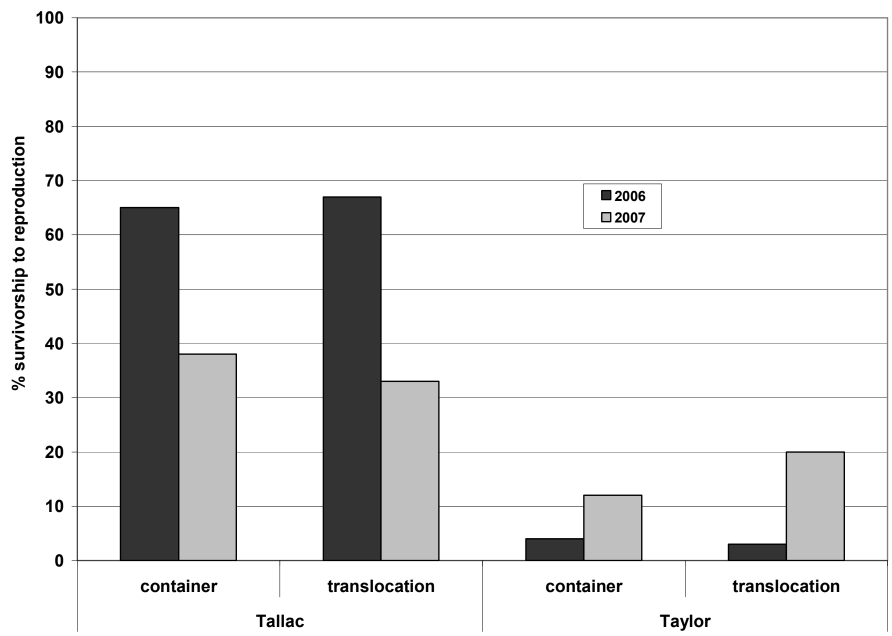

Figure 4. First and second year mean survivorship to reproduction of container-grown and translocated founders at two sites in September of 2006 and 2007.

Overall, second year demographic performance was again more strongly dependant on site characters and lake level than the method of translocation or outplanting container-grown plants. In addition, the continued persistence and robust reproduction of the re-sprouts at Pope helped to offset any losses from the testing of translocation and may have even lead to an increase in seed production at that site.

4.2 Experimental translocations

2007 Experimental translocation

In the 2007 translocation, the pattern of total survivorship of container-grown and translocated plants at the 8 week mark in October was different between the sites, with a greater proportion of translocants surviving at UTE and more container-grown founders surviving at Blackwood (Table 3). The container-grown plants were significantly more likely to survive than translocated plants at Blackwood according to the contingency analysis ($p<0.05$ for both Pearson's Test and Fisher's Exact Test) but there was no significant differences at UTE.

Table 3. Survivorship and canopy size of container-grown and translocated plants at two sites, October 2007 (Values in a column followed by different letters are significantly different within a site [Fisher's Exact Test $p<.05$])

Site	Source	N	# Alive	Canopy (cm^2)
Upper Truckee East	Container	49	22 a	4.38 a
	Translocation	50	29 a	6.62 a
Blackwood	Container	50	28 a	4.63 a
	Translocation	50	17 b	2.66 a

Plants at both sites were very small, regardless of source, and did not reproduce at all. Although the mean canopy size of translocated plants was slightly larger then container-grown plants at UTE, it was the opposite at Blackwood and the differences were not significant.

The overall survivorship of 46% of translocants and 50% of container-grown plants across both sites is rather low compared to outplantings in optimal habitats in past years. For instance, survivorship in the meadow habitat in 2006 was around 85% at all three planted sites and in 2004, total survivorship across all habitats hovered around 75% for most sites. The lower survivorship in 2007 was likely a function of postponing the outplanting date to the beginning of August. Past outplantings have occurred around the time of peak lake elevation from mid-May to early June. The only other late planting occurred in late July, 2004 at UTE. Compared to the June planting that year, reproduction of the July cohort in the optimal berm habitat was reduced by half and founders did not reproduce at all in the high beach indicating that late plantings strongly limit growth and reproduction.

At the first monitoring event of second year survivorship in June, 2008, all but 20 of the 100 stakes at UTE had been removed and incorporated into some "beach art". Only 4 to 6 plants were apparent in the transplanted area- the only likely survivors. The failure of the experimental translocation at this site is the combined result of a late planting date in 2007 that did not allow the plants sufficient time to establish or reproduce and a lack of adequate fencing and signage protecting the experiment and discouraging vandalism.

At Blackwood, a total of 28 small vegetative plants were present in June, representing 28% of the 2007 experimental cohort. Of these, more container-grown plants (17) were present than translocants (11), which is similar to the pattern observed at end of the 2007 growing season. However, by August only 8 plants (4 of each treatment) were present and only two of those had fruit. By September, only 4 tiny, non-reproductive plants were present (2 of each treatment). This planting was not vandalized. While the decline in survivorship over the 2008 season may be the result of the two foot decline in lake level during that period, the ultimate failure of this experiment is likely due to the very late planting date in 2007. The founders that survived to the end of the first year were very tiny and did not reproduce and therefore the plants that appeared at the beginning of the 2008 were the re-sprouted material from what may have been very poorly developed root stock. Third year results from the 2006 cohort of container-grown plants indicate that first year reproduction may be a good predictor of the ability of plants to establish and survive into future years. It may follow that the lack of first year survivorship at Blackwood precluded survivorship in the second year. Since no further useful information could be obtained, the stakes were removed in September.

2008 Experimental translocation

Overall total survivorship of both container-grown and translocated plants was high at both sites, with 73 and 94% of the cohort surviving at Edgewood and UTE, respectively. No difference was observed in survivorship or reproduction rates between container-grown founders and those that were translocated at UTE (Figure 5). However, a significantly greater proportion of translocated than container-grown founders survived to reproduction at Edgewood according to the contingency analysis ($p<0.001$ for both Pearson's Test and Fisher's Exact Test). In contrast to the very poor growth observed in the 2007 experimental translocation, plant growth at both sites was robust. Within a site, the mean canopy size of translocated and container-grown founders was nearly identical, but the mean canopy size of plants was significantly greater at Edgewood than UTE (Figure 6).

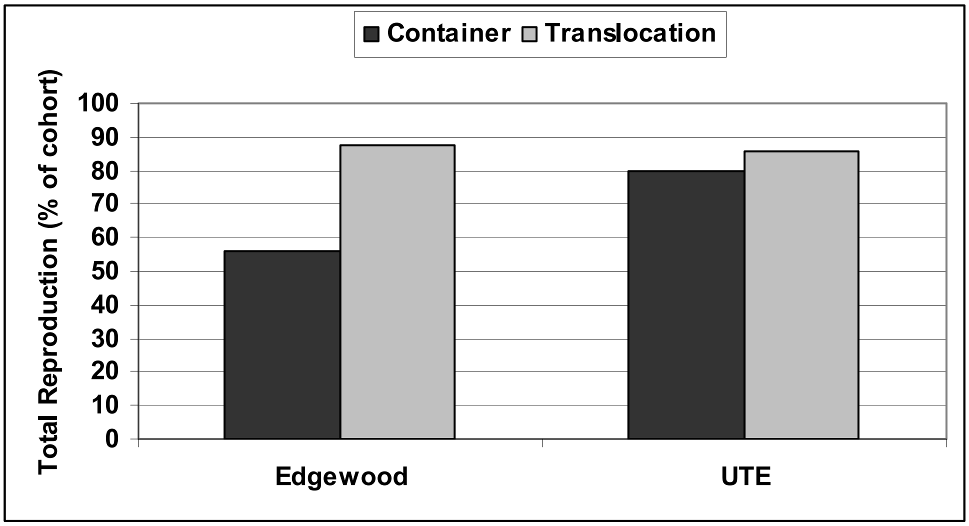

Figure 5. Percent total reproduction in September, 2008 of container-grown and translocated plants at two sites.

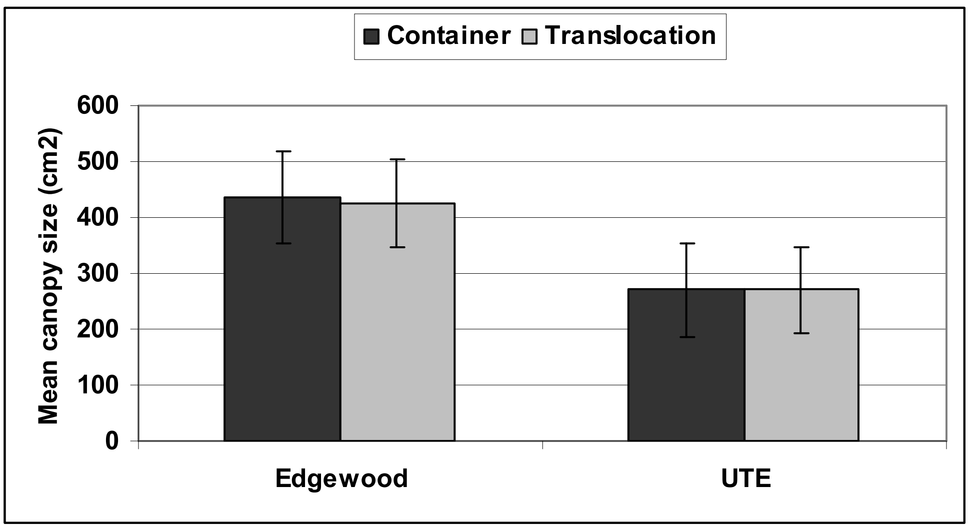

Figure 6. Mean canopy size in September, 2008 of container-grown and translocated plants at two sites.

During the September planting at Edgewood, the monitoring crew observed sprinklers from the golf course reaching the translocation plot on the beach to the point of saturation. The sprinkling systems are hand positioned on the course so this may have not been a regular occurrence, but even the periodic addition of water would have contributed to substantial plant growth and is likely responsible for the observed difference in plant canopy size between the sites.

5.0 Discussion

The first pilot translocation of TYC ever conducted in 2005 was unfortunately compromised by vandalism even though it was within the permanent enclosure at Taylor Creek. First year survivorship of the small group of translocants was estimated at more than 80%, but it was not possible to definitively identify some of the plants or follow them into the next year to determine if they persisted.

The favorable, although inconclusive, results in 2005 provided the impetus to pursue a second translocation in 2006. With the level of Lake Tahoe at its legal limit and the number of occupied sites around the lake reduced from 47 to only 24, the AMWG chose to test translocation of one year and three year old container-grown plants from previous experimental reintroductions. No vandalism occurred in 2006, but translocation was only successful at one of the two sites (Tallac Creek). Physiological measurements of both the translocants and the 2006 cohort of container-grown plants showed that both types of plants at Tallac were less water stressed than those at Taylor, indicating that the moist habitat conditions at Tallac was probably a critical factor in the differential performance between the sites. There was no difference in first year performance between the plants that were translocated and those that were outplanted. Site elevation (depth to the water table) has been show to be a controlling factor in the demographic performance of all of the past experimental reintroductions. The limited data from the translocation along with the experimental reintroduction suggested that the methods of outplanting and translocation can produce similar results, but further testing with greater numbers of plants and more sites would be required. An additional outcome of the 2006 pilot was that the net loss of TYC from the experiment was lessened because one half of the plants that were moved to Taylor re-sprouted in their donor location at Pope.

In their second year, the survivors from the 2006 pilot scale translocation were robust and continued to provide a tangible benefit to the species in the form of an estimated 3,000 seeds. In addition, the continued persistence of the re-sprouts at Pope and robust reproduction of an estimated 10,000 seeds, continued to help offset any losses from the testing of translocation. Second year demographic performance continued to be more strongly dependant on site characters and lake level than the method of translocation or outplanting container-grown plants.

In 2007, the level of Lake Tahoe dropped two feet and 6 more sites around the lake were found to be occupied in the annual surveys in September. The lower lake level, along with the limited data from the pilot scale projects and the increasing pressure surrounding the adoption of a new regional Shorezone Plan, made many members of the AMWG more comfortable with pursuing a full scale translocation experiment in 2007. A paired design comparing the method of translocation of naturally occurring TYC to outplanting of container-grown plants was adopted as meeting the needs of the adaptive management process. However, implementation was delayed until August because the AMWG was debating the terms of using naturally occurring plants in the experiment (see section 3.3) and ultimately only two sites were selected instead of the proposed 4 to 7 sites.

The delays apparently compromised the 2007 translocation. Although roughly half of both the container-grown and the translocants survived to September the first year, the plants at both sites were very small, regardless of source, and did not reproduce at all. In the second year of monitoring, the plot at UTE was vandalized in early 2008, but it appeared that only about 6 individuals may have persisted. No vandalism occurred at

Blackwood, but no plants persisted at that site either. The failure of the experiment was attributed to the late planting date in August. While most outplantings have been conducted around the time of peak lake elevation from mid-May to early June, a previous planting in late July indicated that late plantings strongly limit growth and reproduction.

In 2008, only seven sites met the new site selection criteria requiring a 2007 stem count greater than 400 stems and ultimately only two sites were selected for the translocation experiment. The plants were installed in mid-June and the demographic performance of both container and translocated plants was robust at both sites. While both types of plants performed equally well at UTE, translocated founders performed better than container-grown plants at Edgewood. However, the explanation for the differential performance at Edgewood is not clear. Several hours after the installation, the planting crew returned to find that two container-grown plants had been uprooted- presumably by Canadian Geese. These were re-planted, but some damage was noted within the plot during watering over the next three days, so it is possible that the reduced survivorship of the container-grown plants was due to the geese. It does not appear that TYC is any sort of preferred forage of the geese as they have not been observed directly eating TYC before.

6.0 RECOMMENDATIONS

To date, the pilot and experimental translocations have not provided conclusive evidence regarding the use of translocation as a viable mitigation option. Results from the 2006 pilot experiment at Tallac Creek indicated that translocation is as effective as outplanting of container-grown plants when conducted in optimal habitat. And similar results were produced in the larger scale experiment in 2008 under the optimal habitat conditions at UTE. However, it has not been possible to invalidate our null hypothesis that the methods of translocation and outplanting produce similar demographic performance. In fact, one might expect that container-grown plants would have an advantage because the tube of soil-less potting mix might help buffer from transplant shock by providing a "sponge" that holds more water than the surrounding sand substrate. Generally, the container-grown plants are placed in the ground with the soil from the potting tube still intact because the roots are holding it together in a conical shape. In contrast, the process of uprooting a naturally occurring TYC is an excavation process that gradually exposes a bare root structure composed on one to many root stems and some degree of fine root network. Eventually the main root stem breaks, sometimes after only 10 cm of root have been exposed, other times after more than 50cm is visible, so it is possible that the amount of root that is obtained is an important factor in the survival of translocants.

Another experimental translocation that is conducted at a greater number of sites is clearly required. Plants from that 2008 experiment have persisted into the 2009 growing season and further results will be available this year, however it is not likely that an explanation for the better performance of translocated founders over container-grown plants that occurred at Edgewood will emerge in the second year. Past experimental reintroductions indicate that second year performance generally mimics the pattern established in the first year, but the effect is strongly linked to changes in lake elevation.

A zone on the beach that provided optimal habitat for TYC under high lake level conditions can become inhospitable the following year if the lake drops several feet. Likewise, optimal habitat can become submerged as the lake level rises. The maximum elevation of Lake Tahoe for 2009 was reached in June and it was one and a half feet lower than the maximum in 2008. Therefore, the habitat at Edgewood has become less optimal and the plants may not persist through 2009.

The 2008 experimental translocation is being repeated in 2009 and the scope of the project has expanded to 4 sites, including three USFS beaches (Ebright Beach, Pope Beach, and Nevada Beach) and the enclosure on CTC land at UTE. This year, the translocation is being installed as one of the treatments in an outplanting of container-grown plants designed to test planting time. Every four weeks beginning in mid-June and continuing into September, 50 container-grown plants will be installed at each of the four sites. The translocation was conducted at the time of the first outplanting of the container-grown plants in mid-June at the time of peak lake level. Therefore, it will be possible to compare the performance of the June cohort of container-grown plants to the translocants. In addition, the length of the rootmass was measured on each translocant at the time of extraction, along with plant canopy, in order to determine if root length affects demographic performance.

The test of timing was also conducted in 2008, but not concurrently with the translocation at all sites. First year results were variable, and performance was not as good as expected due to the lower habitat quality of some of the selected sites. Continued monitoring in 2009 will be critical to determine the persistence of the monthly cohorts, especially the effect of planting as late as September. Funds from the Sierra Nevada Public Lands Management Act (SNPLMA) that were earmarked for the Lake Tahoe basin are supporting the ongoing research. The Lake Tahoe Basin Management Unit (LTBMU) is administering an ongoing contract with BMP Ecosciences.

The translocation and the test of timing will need to be monitored into 2010. Results will be used to assess the role of translocation and outplanting of container-grown plants as suitable tools for use in mitigation. It is expected that BMP Ecosciences will pursue additional funding to develop a TYC restoration and management handbook that will address issues on both public and private lands. The handbook should have specific recommendations regarding when, where, and how to install restoration projects and criteria for measuring project success. If translocation proves to produce similar results as outplanting then it will be possible to apply the lessons learned from the successive years of experimental outplantings to the method of translocation and both may be used as tools in mitigation.

8.0 Photos

Photo 1 Container-grown TYC at the NDF Washoe Nursery

Photo 2 Experimental plot protection sign for private sites (Edgewood and Blackwood).

Photo 3 Translocation donor site at Edgewood Golf Course in June, 2009.

Photo 4 TYC donor plants established in the beach collapse at Edgewood.

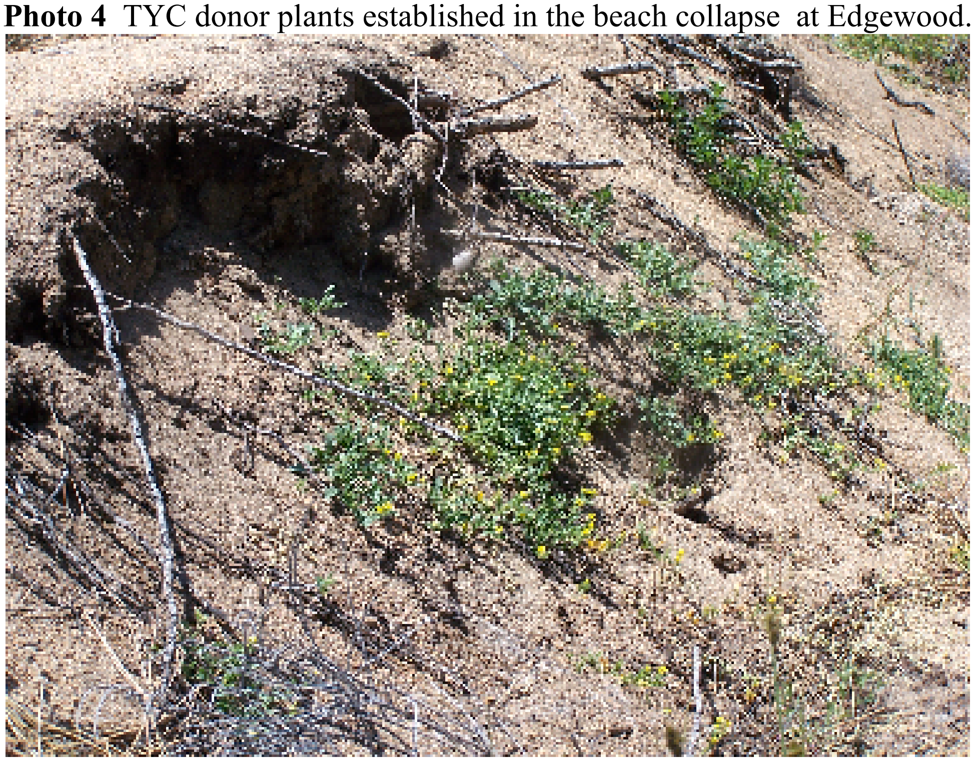

Photo 5 A) Donor site at Blackwood South   B) Receptor site at Blackwood North

A)

B)

Photo 6 Translocation of a naturally occurring plant at Blackwood South on August 3, 2007 (note the rocky substrate).

Photo 7 A) Donor site at UTE in August, 2007. **B)** Receptor site at Upper Truckee East.

A)

B)

Photo 8 Translocant on the left and container-grown TYC on the right at UTE, August 2007.

Photo 9 Extraction of TYC at Tallac Creek in June, 2009.

Photo 10 Extraction of TYC at Tallac Creek in June, 2009.

Photo 11 Partially intact soil tube on a 3yr-old container-grown TYC at Tallac Creek, June, 2009.

Photo 12 Typical naturally occurring TYC translocant with bare roots exposed
(ruler is 46cm or 18 inches).

Photo 13 A) Numbered translocant and B) container-grown plant at UTE in June, 2009.

Photo 14. Container-grown plant in intact soil tube (Nevada Beach 2006 planting).

9.0 References

California State Lands Commission. 2003. Tahoe Yellow Cress (*Rorippa subumbellata*) 2002 Annual Survey Report. Sacramento, CA.

California State Lands Commission. 2002. Tahoe Yellow Cress (*Rorippa subumbellata*) 2001 Annual Survey Report. Sacramento, CA.

California State Lands Commission. 1999. Synopsis of 1999 Tahoe Yellow Cress Annual Surveys. Sacramento, CA.

California State Lands Commission. 1998. Tahoe Yellow Cress Draft Biological Assessment. Sacramento, CA. 45 pp. plus appendices.

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

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

Pavlik, B.M. and A.N. O'Leary. 2002. Implementation of the Conservation Strategy for Tahoe Yellow Cress (*Rorippa subumbellata*). II. Key Management Questions as a Framework for Research. Prepared for the Tahoe Yellow Cress Technical Advisory Group and the Tahoe Regional Planning Agency.

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

Pavlik, B., A. Stanton, and J. Childs. 2002b. Implementation of the Conservation Strategy for Tahoe Yellow Cress (*Rorippa subumbellata*): I. Seed Collection, Assessment of Reproductive Output, and Propagation for Reintroduction. Prepared for the Tahoe Yellow Cress Technical Advisory Group and the Tahoe Regional Planning Agency. Zephyr Cove, NV.

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

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

Pavlik, B., and A. Stanton. 2006. Implementation of the Conservation Strategy for Tahoe Yellow Cress (*Rorippa subumbellata*): V. Experimental Reintroductions: Year Two. Prepared for the Tahoe Yellow Cress Technical Advisory Group and the Tahoe Regional Planning Agency. Stateline, NV.

Pavlik, B., and A. Stanton. 2007. Implementation of the Conservation Strategy for Tahoe Yellow Cress (*Rorippa subumbellata*): VI. Experimental Reintroductions: Year Three. Prepared for the Tahoe Yellow Cress Technical Advisory Group and the US Fish and Wildlife Service, Reno, Nevada.

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

Stanton, A., and B. Pavlik. 2005 2006 2007 2008 2009. Implementation of the Conservation Strategy for Tahoe Yellow Cress (*Rorippa subumbellata*): Annual Reports. Prepared for the Tahoe Yellow Cress Adaptive Management Working Group and Executive Committee