Implementation of the

Conservation Strategy for Tahoe Yellow Cress

(*Rorippa subumbellata*).

II. Key Management Questions as a Framework for Research

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Introduction

In order to organize existing and future research related to Tahoe Yellow Cress (TYC – *Rorippa subumbellata*), five "key management questions" (KMQ's) were developed. These questions are intended to implement the conservation strategy (Pavlik et al. 2002a) by focusing research on the restoration of metapopulation dynamics in the context of ongoing perturbations from fluctuations in lake level and intense anthropogenic impacts. The scientific and management implications of each question are discussed below, along with general and specific examples of the kinds of research that would be addressed. The five key management questions are:

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 or gene pool 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?**

The second part of this report presents expanded examples from four very different areas of inquiry with respect to TYC research; soil characteristics, genetic inventory, recreational activity and restoration. These were chosen to demonstrate how proposed research could be designed to address specific, applied problems faced by land managers, agency regulators, and restoration biologists. The attempt is to harness the power of a scientific approach while keeping the focus on generating information of immediate value to decision-making and adaptive management.

Part I: Key Management Questions and Their Implications

Key Management Question 1:

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

If we knew that natural populations of TYC could occupy virtually any site around the lakeshore, then we would also know that 1) all sites with significant sand deposits were potential habitat, 2) potential habitat is not defined by cryptic factors that allow persistence at some sites but not others, 3) dispersal and other metapopulation events limit site occupancy instead of resource factors, 4) the importance of any one site, especially those that have supported TYC, is much less than previously believed, and 5) site factors, both natural and anthropogenic, could determine the difference between core and satellite populations (e.g. vigorous and persistent vs. weak and transient populations).

Given this knowledge, the job of the regulator would be to maintain a network of actual and potential habitat based upon between-site variations in habitat quality, distance between core and satellite populations, and factors that affect dispersal probabilities between sites (e.g. water current patterns). Less emphasis would be given to protection of any one site, especially low priority restoration sites, because there would be nothing "sacred" about that site that could not be found or duplicated elsewhere. Reintroductions could occur anywhere with sandy habitat and would usually be placed in the aforementioned network (see #3, below).

Therefore, studies that address this management question would resemble the following:

- Environmental characterizations of occupied and unoccupied sites
- Demographic performance between occupied sites (identification of core vs. satellite populations)
- Dynamic links between occupied and unoccupied sites, core and satellite populations
- Changes in ecosystem characteristics between sites

Specifically, hypotheses could be developed that compares different sites relative to

- soil (substrate) physical and chemical characteristics
- beach microtopography and hydrology
- natural disturbance regimes
- shorezone vegetation, especially seral stage effects
- propagule movements and colonization frequency
- water and wind circulation patterns
- air and water quality

Key Management Question 2:

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

If we knew that certain ecosystem factors correlated with variations in the demographic characteristics of natural TYC populations, then we would also know that 1) management actions that affect these factors were likely (or unlikely) to affect nearby TYC populations, 2) trends in certain factors would affect TYC presence and persistence, and 3) the network of actual and potential habitat for TYC (see #1, above) would be affected by a complex set of dynamic factors that would defy simplistic management efforts over time.

Given this knowledge, the job of the regulator would be to work with other agencies to minimize or mitigate deleterious ecosystem trends.

Therefore, studies that address this management question would resemble the following:

- Demographic characterizations within occupied sites with variable microhabitat features
- Effects of runoff water quality on TYC performance at downstream barrier beaches
- Invasive plant and animal impacts
- Patterns of waterfowl migration and beach use
- Effects of reservoir operation on dynamics of TYC populations

Specifically, hypotheses could be developed that evaluates

- stream nutrient loading due to wildfire, retention basin construction, sewer improvements

- Impacts of construction or recreation on Canada geese resting behaviors
- Reservoir management in high and low lake level

Key Management Question 3:

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

If we knew that TYC populations could be created (by reintroduction) in appropriate habitat (see #1, above), or that populations with few individuals (e.g. < 100 stems, Pavlik et al. 2002a) readily enlarged (by enhancement), then we would also know that 1) core populations could be developed within most lake quartiles, 2) restoration of metapopulation dynamics (i.e. core to satellite dispersal and colonization) would be possible, 3) mitigation measures would be potentially effective, and 4) land owners or managers would have a greater range of mitigation measures and, therefore, greater flexibility in the design and execution of their projects.

Given this knowledge, the job of the regulator would be to ensure that large (> 1200 stems), vigorous core populations occupied all (or nearly all) lake quartiles. Disturbance caused by human activities would be fully mitigated in the context of attempting to restore a positive dynamic between core and satellite populations occupying a network of actual and potential habitat (see #1, above). Less emphasis would be given to protection of individual plants, small or ephemeral populations, or sites that fail to sustain created or enlarged populations. Reintroductions could occur anywhere with sandy habitat and would usually be placed in the aforementioned network.

Therefore, studies that address this management question would resemble the following:

- Site factors that determine success of reintroduction or enhancement (e.g. microtopography, hydrology, microclimate)
- Founder gene pool composition (i.e. whether to blend founders from different source populations, see #4 below)
- Logistic and security factors that affect establishment (e.g. human disturbance)
- Experimental reintroductions in occupied and unoccupied sites

Specifically, hypotheses could be developed about

- genetics of founding propagules
- reintroduction designs and techniques
- monitoring protocols
- minimum viable founding populations

Key Management Question 4:

Can any TYC genotype or gene pool perform equally well at any appropriate site?

If we knew that any geographically defined strain of TYC could germinate, grow and reproduce to the same extent at any suitable site around the lake, then we would also know that 1) the small detectable electrophoretic distinctions between populations were not site-specific, and therefore not the product of local selection, 2) known gradients in precipitation, air temperature, substrate mineralogy, and fluvial dynamics are less important than metapopulation processes in determining presence or persistence, 3) the vast majority of relevant genetic variation would be captured in a handful of large populations, and 4) it is extremely unlikely that microhabitat variants occur within any one population.

Given this knowledge, the job of the regulator would be to ensure the genetic integrity of a few, large core populations while being less concerned with the composition of smaller, ephemeral satellite populations. Reintroductions could use almost any source of TYC seed, accept those that restored large, core populations. Less emphasis would be given to protection of any one small population because there would be nothing “sacred” about that particular gene pool.

Therefore, studies that address this management question would resemble the following:

- Genetic characterizations of TYC populations
- Common garden studies of physiological and demographic performance
- Comparisons of TYC and *Rorippa curvisilique* performance in a common garden

Specifically hypotheses could be developed about:

- determination of chromosome counts
- electrophoretic comparisons of large and small populations
- ecogeographic patterning of genetic variation
- effects of clonal vs. sexual reproduction on gene pool structure

Key Management Question 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?

If we knew that "safe sites" for TYC could be created or found under any human use regime, then we would also know that 1) certain populations found in particular microhabitats would receive less impact than other populations simply because human use patterns do not concentrate impacts in those microhabitats, 2) certain structures for enclosing the population would be more effective than others, 3) certain structures or access designs for redirecting visitor impacts would be more effective than others, 4) limits on certain types and frequencies of impacts could be derived from empirical studies in order to set thresholds in open areas, 5) such limits would vary with site conformation, phenological state of the population and the seasonal timing of the impact.

Given this knowledge, the job of the regulator would be to determine the fundamental characteristics of the impacts at hand (type, intensity, frequency, timing), and then select the kinds of structures or access designs to be installed. In some sites, no structures may be necessary given the microhabitat preferences of the population and the location of the impacts. However, they may be situations where projected impacts would be unacceptable and site closure therefore necessary.

Therefore, studies that address this management question would resemble the following:

- Effects of different fencing on impact control and TYC population attributes
- Temporal and spatial characterizations of different human use activities (e.g. beachgoing vs. kayak landing vs. Fourth of July partying)
- Control of construction impacts
- Controlling passive use impacts, such as nature study, education

Specifically hypotheses could be developed about:

- testing fencing efficacy with respect to people, dogs, vehicles, construction
- use of boardwalks, signage, kiosks
- minimum security for completely closed sites

Part II: Expanded Examples of Research in the KMQ Framework

Example 1: Soil Characteristics Associated with TYC and its Habitats

Lead Agency: U.S. Forest Service, Lake Tahoe Basin Management Unit, CA
Contacts: Gail Durham and Denise Downey
Year Conducted: 2002
Reference: G. Durham, pers. comm. 5/24/2002

Herein we propose a design for sampling soil physical and chemical characteristics to address key management questions (KMQ's) related to the conservation of Tahoe Yellow Cress (TYC - *Rorippa subumbellata*). Primary KMQ's are the most general, and were previously chosen to organize all research efforts in relation to TYC (see part I, above). Secondary KMQ's are those formulated for a specific area of inquiry, in this case, soil characteristics. Beneath each secondary KMQ is a null hypothesis (Ho) and a statement of the general approach and suggested level of sampling effort required to test the hypothesis. Site and replicate suggestions for testing these specific, soil-oriented hypotheses are made in Table 1.

Soil characteristics (e.g. nutrient status, surface armoring, texture) have often been invoked to explain the observed patterns of TYC distribution and abundance (Pavlik et al. 2002a), but there have been virtually no scientific studies conducted. Osborne et al. (1985) conducted a survey of near-shore sediments in the basin and demonstrated that Tahoe beach sands are highly compartmentalized around the perimeter of the lake, reflecting local sources, sorting and depositional processes. There was no attempt to link the individual sands with the presence or absence of TYC at any given site.

KEY MANAGEMENT QUESTION 1 (EXAMPLE 1):

CAN TYC POPULATIONS OCCUPY ANY SITE OR MICROHABITAT AROUND THE LAKE MARGIN THAT HAS SANDY BEACH HABITAT?

Secondary Key Management Question:

Do soil physical and/or chemical characteristics distinguish between occupied (actual habitat) and unoccupied (potential habitat) sites?

Null Hypothesis 1: Occupied and unoccupied sites do not significantly differ in their soil physical and/or chemical characteristics.

Approach: Sample a spectrum of USFS sites with (or having had) and without (never having had) TYC populations (Table 1). A standard sampling position (in relation to TYC plants, waterline and beach width) and standard sampling depth (in relation to TYC root zone) will be selected *a priori* . Sample size = 3 to 5 per site, at least 18 sites).

Secondary Key Management Question:

Do occupied sites that have been previously characterized as core, restoration, or unranked, predictively vary in their soil physical and/or chemical characteristics?

Null Hypothesis 2: Core, restoration and unranked sites do not predictively vary in their physical and/or chemical characteristics.

Approach: Sample a spectrum of USFS sites with (or having had) TYC populations that belong to different rank categories (Tables 10 and 11 of the CS). A standard sampling position (in relation to TYC plants, waterline and beach width) and standard sampling depth (in relation to TYC root zone) will be selected *a priori* . Sample size = 3 to 5 per site, at least 9 sites, 2 or 3 sites per rank category.

KEY MANAGEMENT QUESTION 2 (EXAMPLE 1):

ARE THERE ECOSYSTEM FACTORS THAT CAN AFFECT TYC PERFORMANCE WITHIN A GIVEN SITE OR MICROHABITAT?

Secondary Key Management Question:

Do soil physical and/or chemical characteristics distinguish between occupied and unoccupied microhabitats within a site?

Null Hypothesis 3: Occupied and unoccupied microhabitats within a site do not significantly differ in soil physical and/or chemical characteristics.

Approach: Sample a subset of USFS sites with (or having had) TYC populations. Select two locations within each site, one near the existing population center and one beyond the edge of the population by at least 20 m. A standard sampling position (in relation to TYC plants, waterline and beach width) and standard sampling depth (in relation to TYC root zone) will be selected *a priori* . . Sample size = 3 to 5 per location, 2 locations per site (within and beyond plants), and 3 or 4 sites.

Secondary Key Management Question:

Is there a microhabitat gradient in soil physical and/or chemical characteristics from the waterline to the back beach? From soil surface to the water table? From areas with potential nitrogen-fixing plants (e.g. *Alnus incana* var. *tenuifolia*, *Lupinus lepidus*) to areas without?

Null Hypothesis 4: There is no consistent gradient in soil physical and/or chemical characteristics from the waterline to the back beach.

Approach: Sample a subset of USFS sites with TYC populations. In an area near, but not in, the center of the population, divide the beach width into thirds. The first third includes the waterline, berm and stormwave zone. Sample from the center of this zone 1. The second third includes the open, gently sloping and low cover beach. Sample from the center of this zone 2. The last third includes the leading edge of stabilized vegetation. Sample from the center of this zone 3. Sample size = 3 to 5 per zone, 3 zones per site, and 3 or 4 sites.

Null Hypothesis 5: There is no consistent gradient soil physical and/or chemical characteristics from the soil surface to the watertable.

Approach: Sample a subset of USFS sites with TYC populations. In an area near, but not in, the center of the population, dig or augur a borehole. Obtain samples from the first 3 cm (surface stratum), the TYC root zone (stratum at roughly 10-50 cm depth), and within the wet soil that marks the watertable (wet stratum). If the water table is shallow at a particular site, divide the borehole into thirds and sample accordingly (surface, second third, bottom third). Sample size = 1 per stratum, 3 strata/borehole, 4 boreholes per site, and 2 sites.

Null Hypothesis 6: There is no consistent pattern in soil physical and/or chemical characteristics in relation to potential nitrogen-fixing plants.

Approach: Sample a subset of USFS sites with TYC populations and potentially nitrogen-fixing species. In an area within 10 cm of the canopy edge of the nitrogen-fixing plants, dig or augur a borehole. Obtain samples from the TYC root zone (stratum at roughly 10-50 cm depth). If the water table is shallow at a particular site, divide the borehole into thirds and sample the second third. Repeat at a distance of 2 meters away from the nitrogen-fixing plant in the direction of the lake. Sample size = 1 per stratum, 1 strata/borehole, 4 boreholes per site near the fixing plants and 4 boreholes per site away from the fixing plants, and 2 sites.

Secondary Key Management Question:

Do soil physical and/or chemical characteristics within a site vary between microhabitats that support chlorotic, small and/or minimally reproductive TYC plants and those that support green, large, and reproductive individuals?

Null Hypothesis 7: There is no consistent pattern in soil physical and/or chemical characteristics in relation to TYC plants that vary in terms of color, size or reproductive vigor.

Approach: Sample a subset of USFS sites with TYC populations that have been observed to vary in color, size or reproductive vigor. For example, Taylor Creek has chlorotic, small plants and large, robust plants in different areas (CSLC 1998). Cascade, Baldwin Beach have robust plants, while the few observed at Meeks Bay and Pope/Kiva are either chlorotic or minimally reproductive (CSLC 1998). In an area within 10 cm of the canopy edge of the chlorotic/small plants, dig or augur a borehole. Obtain samples from the TYC root zone (stratum at roughly 10-50 cm depth). If the water table is shallow at a particular site, divide the borehole into thirds and sample the second third. Repeat in an area of robust plants. Quantify the differences between chlorotic/small, and robust plants. Sample size = 1 per stratum, 1 strata/borehole, 4 boreholes per site near the chlorotic/small plants and 4 boreholes per site near the robust plants, and 2 sites.

Example 2: Genetic Inventory of TYC

Lead Agencies: National Forest Genetic Electrophoresis Laboratory, Placerville, CA and United States Fish and Wildlife Service, Reno, NV

Contacts: Valerie Hipkins and Jody Fraser

Year Conducted: 2002

Reference: V. Hipkins and J. Fraser, Scope of Work 7/15/02

Herein we suggest a KMQ framework for testing hypotheses related to the genetic structure of Tahoe Yellow Cress populations (TYC - *Rorippa subumbellata*). The primary KMQ is the most general, and was previously chosen to organize all research efforts in relation to TYC (see part I, above). Secondary KMQ's are those formulated for a specific area of inquiry, in this case, genetic inventory. Beneath each secondary KMQ is a null hypothesis (Ho) and a statement of the general approach and suggested ways of sampling or processing data to test the hypothesis.

Concerns over the conservation status of *R. subumbellata* produced a useful appraisal of the quality and abundance of its genomic variability. A pilot study was conducted using vegetative samples collected in July 1996 from Upper Truckee East and Taylor Creek (Bair 1997). A total of 14 enzyme systems were resolved on starch gels using isozyme electrophoresis. No variation was found at 18 of 19 loci examined. The lack of genetic variability form sites more than 4 km apart was "somewhat surprising", but the band resolution was good and further efforts were warranted.

A more robust genetic inventory of TYC was subsequently performed (Saich and Hipkins 2000) which also used isozyme electrophoresis to characterize 140 individuals from 11 populations around the south shore of the lake (see Table 1 of Pavlik et al. 2002a). A total of 16 enzyme systems were resolved on starch gels and interpreted under the assumption that TYC is diploid. The 16 enzyme systems revealed a total of 23 loci. The proportion of all loci that were polymorphic was 13%, with an average of 1.13 alleles per locus. Most sites were monomorphic and completely homozygotic with respect to all loci. Compared to other plants that have been inventoried by starch gel electrophoresis (Hamrick et al. 1979, 1991), TYC has very low levels of isozyme variation and no significant population differentiation. Extensive sampling (i.e. from sites along the west, north and east shores of the lake) could find additional unique alleles, more population differentiation and more ecogeographic (i.e. ecotypic) patterning.

KEY MANAGEMENT QUESTION 4 (EXAMPLE 2):

Can any TYC genotype or gene pool perform equally well at any appropriate site?

Secondary Key Management Question:

Are spatially separated populations of TYC genetically distinct?

Null Hypothesis 1: Populations of TYC do not contain different allozymes or heterozygote frequencies.

Approach: Sample populations that have never been genetically inventoried (e.g. Meeks Bay, Cascade, Tallac Creek, Cave Rock, Glenbrook) or have not been large enough in the past to provide an adequate number of individual plants (e.g. Baldwin W, Upper Truckee W, Kahle/Nevada Beach). Standard sampling protocols (e.g. Falk et al. 1991) that have been used in previous TYC studies (Bair 1997, Saich and Hipkins 2000) should be followed so that previous data can be pooled with new data. This will provide the more extensive inventory to detect ecogeographic differentiation and patterning (Pavlik et al. 2002a). If greater allelic variation is found, and if it can be correlated with spatial or habitat factors (e.g. east-west gradients, berms vs. dunes), then hypothesis 1 can be rejected. This would imply that particular TYC genotypes perform better than others at a given site.

Secondary Key Management Question:

Do populations that undergo large fluctuations in size have less genetic variation than relatively stable populations?

Null Hypothesis 2: Similar levels of allozyme variation and heterozygote frequency are found in all populations regardless of stability.

Approach: Sample populations (and/or analyze pooled inventory data) that have undergone large and small fluctuations in size (Appendices E and F of Pavlik et al. 2002a). Two conditions must be met; 1) Plants must be available in this year for sampling and allozyme inventory (see 2001 and 2002 annual survey data) so that data sets (new or pooled) for each population are based on 25-30 individual plants, and 2) Coefficients of variation (CV's) in mean stem count are based on at least five or six survey estimates. Populations that meet these conditions that have with relatively small coefficients of variation in mean stem count data are Blackwood North (CV = 70.5%, n = 9), Tallac Creek (CV = 37.8%, n = 7), and Edgewood (CV = 71.2%, n = 10). These populations have a mean CV = 59.8%. Populations that meet the conditions that have relatively large coefficients of variation in mean stem count data are Blackwood South (CV = 100.1%, n = 9), Taylor Creek (CV = 97.4%, n = 13), Upper Truckee West (CV = 105.4%, n = 9), Upper Truckee East (CV = 112.1, n = 9), Tahoe Meadows (CV = 96.2, n = 6), and Kahle/Nevada Beach (CV = 139.2 %, n = 14). These populations have a mean CV = 108.4%. **Assumption:** If hypothesis 2 is rejected, it will because more stable populations will contain more, rather than less, genetic variation relative to less stable populations. Rejection (and conformation to the assumption) would allow the possibility that stable populations, regardless of their mean size, may derive some of that stability from greater genetic variation. Perhaps greater genetic variation allows more stress tolerance or a wider distribution among microhabitats within a given site. Therefore, building genetic variation into new or enhanced populations should become a component of restoration efforts because certain gene pools offer more stability than others.

Secondary Key Management Question:

Does the common yellow cress, *Rorippa curvisilique*, exhibit the same levels and patterns of genetic variation at the rare TYC?

Null Hypothesis 3: Similar levels of allozyme variation and heterozygote frequency are found in the common yellow cress as in the rare yellow cress.

Approach: Sample populations of *Rorippa curvisilique* that co-occur with TYC and conduct a genetic inventory. Samples should keep track of which microhabitats are occupied by *R.*

curvisilique at a given site and could be stratified accordingly (e.g. samples from near the water's edge, beach trough, dune). In general, common congeners of rare plants have higher levels of genetic variability and occupy a wider range of microhabitats (Hamrick et al. 1991). If the data generated herein conformed, then we would reject the hypothesis (in other words, the common species is common because of its higher levels of allozyme variation) and conclude that TYC could be constrained by its available genetic variation. However, if the data did not conflict with the hypothesis, then the relative success of *R. curvisilique* would be attributed to its life history traits (e.g. dispersal ability, seed longevity, germination requirements, etc).

Example 3: Fencing TYC Sites with Different Recreational Uses

Lead Agency: California Tahoe Conservancy, South Lake Tahoe, CA
Contacts: Beth Gross and Rick Robinson
Year Conducted: 2000-2001
Reference: B. Gross 2001

Herein we suggest a KMQ framework for testing hypotheses related to recreational activity and the efficacy of fencing to protect Tahoe Yellow Cress (TYC – *Rorippa subumbellatu*). Beth Gross's study (2001) evaluated changes in TYC populations after replacing split-rail zigzag fences with a T-post wire fence at Baldwin Beach, Taylor Creek and Upper Truckee East. The T-post fencing was chosen to minimize the obstruction of wind-driven sand movement. The sites differ in the intensity and type of recreation activity; Baldwin and Taylor receive heavy, almost constant visitor use (e.g. sunbathing, picnics, beach games) while Upper Truckee East receives light and intermittent use (e.g. shore strolling, nature observation). Permanent vegetation sampling transects were then installed at the three sites. At all three sites the percent cover of TYC increased from 2000 to 2001. More sampling would have to be done to document the efficacy of fencing or access designs that would minimize human impacts.

KEY MANAGEMENT QUESTION 5 (EXAMPLE 3):

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

Secondary Key Management Question:

Do different forms of recreational activity result in different levels of TYC protection when fencing has been installed?

Null Hypothesis 1: Regardless of differences in the type and intensity of recreation, T-post wire fences afford the same level of protection from human disturbance.

Approach: Sites with apparently different types of recreational activity (due to access, popularity, history of use) and important, fenced populations of TYC will be selected. Sites such as Baldwin Beach and Taylor Creek receive heavy, almost constant visitor use (e.g. sunbathing, picnics, beach games) while sites similar to Upper Truckee East receive light and intermittent use (e.g. shore strolling, nature observation). Permanent sampling transects would have to be installed within the enclosures and outside the enclosures. Late-summer sampling for several years would be used to make comparisons between and within sites (inside and outside of the fences).by recording the; 1) cover of all vascular plants, 2) density of TYC stems, and 3) relevant measures of recreational impact (cover by foot craters, refuse). If it was shown that recreational impacts differed between sites, then differences in vegetation trends observed outside and inside the enclosures could explained (but only if consistent since there is no replication in this quasi-experimental design). Fenced TYC populations at sites with heavy recreational activity may be subjected to more incursions and disruptions. Conversely, fenced TYC populations at sites with minimal recreation use might not be subjected to disturbances of concern to TYC conservation. Therefore, rejection of the null hypothesis would suggest that fencing types could differ between sites (see hypothesis 2, below).

Secondary Key Management Question:

Can different types of fencing be equally effective in protecting TYC at sites with different forms of recreational activity?

Null Hypothesis 2: Zigzag split rail and T-post wire fencing provide equal levels of protection at sites with light and heavy levels of recreational activity, respectively.

Approach: Sites with documented differences in recreational activity (by testing null hypothesis 1, above) and important populations of TYC would be fenced. Sites with heavy activity (due to access, popularity, history of use) would be fenced with T-post wire fencing as it is probably the most effective and safe type that could be employed (as opposed to T-post barbed wire). Sites with light activity would be fenced with the less effective (due to low height) but more aesthetically pleasing zigzag split rail. Permanent sampling transects would have to be installed within the enclosures and outside the enclosures. Late-summer sampling for several years would be used to make comparisons between and within sites (inside and outside of the fences).by recording the; 1) cover of all vascular plants, 2) density of TYC stems, and 3) relevant measures of recreational impact (cover by foot craters, refuse). If it was shown that recreational impacts differed between sites, then differences in vegetation trends observed outside and inside the enclosures could explained (but only if consistent since there is no replication in this quasi-experimental design). TYC populations at sites with heavy recreational activity should be adequately protected by the T-post wire type. Conversely, TYC populations at sites with minimal recreation use should receive the same level of protection as sites with the T-post wire type. Therefore, rejection of the null hypothesis would suggest that fencing types could not differ between sites and that a consistent standard of the highest, most effective fencing should be applied universally.

This approach could also be used to test the efficacy of temporary fencing (e.g. plastic roll-out) used to protect new colonizations of TYC or short-term experiments or restoration projects.

Secondary Key Management Question:

Do different types of signs more effective than others in reducing recreational impacts to TYC populations?

Null Hypothesis 3: Signs with restrictive messages that threaten enforcement actions are no more effective that signs with educational messages that appeal to a sense of stewardship.

Approach: Sites with documented differences in recreational activity (by testing null hypothesis 1, above) and important populations of TYC would be fenced appropriately (by testing null hypothesis 2, above). At some sites with heavy recreational impact the restrictive/threatening sign (RT) would be used to inform the public of the reason and value of the enclosure. At other sites with heavy recreational impact the educational/stewardship sign (ES) would be installed. Rapid assessment techniques (e.g. temporary step transects) could be used to detect different levels of disturbance within and outside the fenced areas at RT and ES sites. The same could be done at sites with light recreational impact. In addition, interviews with beach users could assess their immediate reaction to the different kinds of signs.

Example 4: Restoring TYC with Experimental Reintroductions

Lead Agencies: TYC Technical Advisory Group, c/o Tahoe Regional Planning Agency, Zephyr Cove, NV

Contacts: Jerry Dion and Bruce Pavlik

Year Conducted: 2003

Reference: Pavlik et al. 2002a, Pavlik 1994, 1995, 1996

Herein we suggest a KMQ framework for testing hypotheses related to restoring populations of Tahoe Yellow Cress using experimental reintroductions. The primary KMQ is the most general, and was previously chosen to organize all research efforts in relation to TYC (see part I, above). Secondary KMQ's are those formulated for a specific area of inquiry, in this case, restoration through reintroduction. Beneath each secondary KMQ are a null hypothesis (Ho) and a statement of the general approach and suggested ways of sampling, designing an experiment or processing data to test the hypothesis.

We intend to implement a program of reintroductions to determine the habitat conditions, logistical factors, and best management practices that will optimize the chances for successful restoration. The project will be designed to install several thousand container-grown plants at three core and priority restoration sites. A structured approach, with demographic and physiological monitoring, is necessary to provide data that will inform the adaptive management process and answer key management questions.

Key Management Question 3 (Example 4):

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

Secondary Key Management Question:

How does microtopography at the time of outplanting affect the first-year demographic performance of reintroduced TYC populations?

Null Hypothesis 1: Vital rates of container-grown TYC plants will be the same regardless of microtopographically-defined microhabitats.

Approach: Container-grown TYC will be outplanted into different microhabitats that are defined by their topographic characteristics at the time of planting (e.g. berm, trough, beach plinth, and foredune). These microhabitats are typically found along complex or simple gradients from the lakeshore towards the inland stabilized dunes or regional vegetation (e.g. ponderosa pine-big sagebrush). In general, complex gradients are found at large, topographically heterogeneous sites and contain at least four microhabitats. Simple gradients are found a smaller, more homogeneous sites with a single, linear transition from wet to dry (e.g. nearshore to backshore).

Within each available microhabitat we will install a randomized-block design containing variables of source site (gene pool) and plant size/age. The exact arrangement of the block design at any given site is part of the layout task performed in 2002. Sites with complex gradients will test four microhabitats while sites with simple gradients will test only two. Five replicate (demographic) blocks of 50 plants each will be arranged in a 4 m wide strip running parallel to the shore and containing a microhabitat. Blocks will contain randomly assigned plants from each source and size/age class, well spaced, randomly arranged but permanently mapped to retain all propagation information. Access buffers will separate blocks to minimize disturbance during outplanting and monitoring.

Demographic monitoring will measure vital rates of the founding population, including mortality, survivorship to reproduction, plant size and fruit output (fecundity).

Secondary Key Management Question:

Is the hydrological variable important, rather than microtopography *per se*, in the first-year performance of reintroduced TYC populations?

Null Hypothesis 2: Stem water potentials of container-grown TYC plants will be the same regardless of microtopographically-defined microhabitats.

Approach: Container-grown TYC that have been outplanted into different microhabitats will necessarily be at different vertical distances from the water table. The roots of plants in the berm and trough microhabitats (nearshore) will quickly grow into the permanently wet layers of the soil and should have stem water potentials that reflect access to a constant moisture source. Roots of plants in the beach plinth and dune microhabitats will have to grow down through the sand deposits, following soil moisture horizons originating from winter and spring precipitation. These horizons will disappear during the early summer, potentially exposing these plants to greater levels of stress (i.e. lower stem water potentials).

Plants in the randomized-block design will be physiologically monitoring during the spring, summer and fall using a Scholander pressure bomb. Stem xylem water potentials will be correlated with measures of survivorship to reproduction, plant size and fruit output (fecundity) obtained from the demographic monitoring.

Secondary Key Management Question:

Can seeds be used as a propagule source for reintroduction of TYC?

Null Hypothesis 3: Vital rates of TYC seeds will be the same regardless of microtopographically defined microhabitats.

Approach: Seeds of TYC will be outplanted into different microhabitats using collections made in 2002 from source populations. They will be precision-sown (Pavlik et al. 1993, Pavlik 1995) so that field emergence (germination) and seedling mortality can be monitored in addition to survivorship to reproduction, plant size, and fruit output (fecundity). The experiment can be done at sites with complex, simple, or no gradients (e.g. those with a single microhabitat patch).

Within each available microhabitat we will install a randomized-block design containing the variable of source site (gene pool). The exact arrangement of the block design at any given site is part of the layout task performed in 2002. Sites with complex gradients can test four microhabitats, sites with simple gradients can test only two and sites with patches only one (see below). Five replicate (demographic) blocks of 100 seeds each will be arranged in a 2 m wide strip running parallel to the shore and containing a microhabitat. Blocks will contain seeds from each source, well-spaced, randomly arranged but permanently mapped to retain all information. Access buffers will separate blocks to minimize disturbance during outplanting and monitoring.

Demographic monitoring will measure vital rates of the founding population, including field emergence, seedling mortality, survivorship to reproduction, plant size and fruit output (fecundity).

Key Management Question 3 (Example 4):

Can any TYC genotype or gene pool perform equally well at any appropriate site?

Secondary Key Management Question:

Do founders from different natural populations perform equally well at all reintroduction sites?

Null Hypothesis 1: Vital rates of container-grown TYC plants from different source populations will be the same in similar microtopographically defined microhabitats.

Approach: Container-grown TYC will be outplanted into different microhabitats that are defined by topographic characteristics (e.g. berm, trough, beach plinth, and foredune). These plants will be derived from different source populations around the lake (see Pavlik et al. 2002b). During outplanting we will record the sources of the founders while randomly assigning them to treatment blocks (see 3a, above).

Demographic monitoring will measure vital rates of the founding population, including mortality, survivorship to reproduction, plant size and fruit output (fecundity). Comparisons of relative performance within a microhabitat can be analyzed as a common garden or reciprocal transplant experiment by respectively comparing vital rates of 1) different sources at the same site and microhabitat or 2) the same source at different sites in the same microhabitat.

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Ecostystem factors correlated with variations in the demographic characteristics of TYC populations

Studies that address this management question would resemble the following
Patterns of waterfowl migration and beach use- impacts of construction or recreation on Canadian geese resting behaviors

Beth Gross' study did the following:
Fencing: Zigzag enclosures at Baldwin Beach were replaced with T-post fencing with coated smooth wire allowing for less inhibited movement of sand. Taylor creek enclosure increased in size, 10-15 ft closer to the shoreline.
Sample Baldwin Beach, Taylor Creek, and Upper Truckee East enclosures
Evaluate the percent cover of each vegetative species found within the study areas
Continue the 2000 Spatial Distribution Monitoring protocol at Baldwin Beach and Taylor Creek enclosures
Revise the monitoring protocol at Upper Truckee East and install permanent transects

Baldwin Beach enclosure: TYC increase in cover class rating and decrease in cover for most other species. No new establishment of TYC individuals were noted. The design of the enclosure did not allow for lateral expansion. Cover class rating of TYC was 0.2616 with the presence/ansence plots included. The 2000 cover class rating was 0.10031.

Taylor Creek enclosure: Cover class rating for TYC increased from 0.057838 in 2000 to 0.1931. Emergence of TYC Juveniles within three feet of the lagoon's edge. Newly established species formed a vegetation band around the backwater lagoon and overall species diversity increased.
Upper Truckee East: The cover class rating for TYC was .19257, and had the fourth highest cover class value out of sixty species. It is one of the prominent species found within the littoral zone. TYC was found within bands of vegetation three to four feet from the water's edge. There is a minimal amount of recreational disturbance at this site. TYC migrated in June and July from the backshore area to the foreshore area as the lake dropped over its growing season. Many of the individuals found at Upper Truckee east were in the flowering and seedling stages.

Continue this monitoring protocol within the established transects?