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COLONIZATION AND INVASION OF A LAKE DRAWDOWN
IN THE MOJAVE DESERT

by

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ABSTRACT

Colonization and Invasion of a Lake Drawdown in the Mojave Desert

by

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I examined the colonization patterns of plants in the drawdown zone of Lake Mead. There was an increase in the mean number of species over time as well as differences in the colonization patterns of two non-native plant species, *Brassica tournefortii* and *Tamarix ramosissima*. I also examined the impact of germination order on competition between *B. tournefortii* and four native species under controlled environmental conditions and found effects of germination order on both aboveground and belowground biomass for all species in the study. These results can aid management of the Lake Mead drawdown zone by providing an overview of how the community develops and where non-native species are likely to invade. Also, this study indicates that competitive relationships between the non-native *B. tournefortii* and four common native species should be considered in any efforts to control *B. tournefortii.*

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CHAPTER 1

INTRODUCTION

This study examined colonization and invasion dynamics in the drawdown zone of Lake Mead in the Mojave Desert. Colonization, which initiates succession (the sequential replacement of plant communities), is the establishment of a plant species in an area where that species did not previously exist. Invasion is a slightly more complex term. Some studies define an invasive species merely as an introduced species that has become a pest species (Usher 1988). Other authors (Cronk and Fuller 1995) define an invasive species as an alien species that spreads without human assistance and produces a significant change in community composition, community structure or ecosystem processes. Both of these definitions focus on an invasive species as an "alien" or a non-native species, but this is not always the case. In fact, in Europe and Mexico the majority of the "weedy" or "pest" species are actually native species (Williamson 1996). However, for the purpose of this study, an invasive species is defined as a non-native species capable of becoming dominant in an area, either a result of a large number of individuals or increased cover, resource use, or some other ecological impact (Rejmanek 1995).

Succession, a sequence of colonization of flora in which communities are replaced by increasingly more stable communities (Connell and Slatyer 1977), generally follows a disturbance such as a landslide, a fire, a drought or a flood. Each of these disturbances creates a different substrate upon which succession will occur. For example, a landslide may remove all of the existing biota as well as the top layer of soil. On the other hand, a flood may leave a percentage of the pre-existing biota but wash away the top layers of soil. The successional patterns expected to occur following a disturbance depend on the substrate that remains after the disturbance. Therefore, most successional studies are classified as either primary or secondary succession. These two definitions should be considered a continuum of potential successional outcomes as opposed to two distinct and limited categories. Generally, however, primary succession is defined as succession that occurs on substrates where the original biota has been removed and mixing of the top soil layers has removed organization of the soil (Walker 1999). Secondary succession encompasses all other situations.

Hoover Dam, which was completed in 1935, created the reservoir Lake Mead. Lake Mead is located in Lake Mead National Recreation Area, a 607,028 hectare park in the Mojave Desert. Lake Mead serves as the water source for the Las Vegas Valley and Las Vegas. A drought in 2000 resulted in a decline in the water level in Lake Mead. This drought has continued until the time of this writing. The drawdown zone, the landscape that emerges from the water as the water level in the lake declines, provides an opportunity to study primary succession and invasion in a desert system. The expanse of land at Lake Mead NRA that has emerged since 2000 had been under water for ten years (Figure 2-1). The exposed land was devoid of plant communities and, as a result, is representative of primary succession (Walker and del Moral 2003). Not only was the drawdown zone at Lake Mead NRA an excellent location for the study of primary succession, but reservoirs have been shown to accelerate the rate of invasions into surrounding habitats (Havel et al. 2005). The Lake Mead reservoir, therefore, is an ideal site for the study of primary succession and invasion as well as the interaction of the two processes.

There is on-going debate over the occurrence of succession in desert systems (Goldberg and Turner 1986; Turner 1990) resulting in a paucity of research on succession in deserts. Community formation in the desert often occurs slowly, due to the harsh conditions; therefore, successional patterns are not easily detected. Also, any species that is able to survive the harsh conditions of the desert is likely to be relatively stable (long-lived). However, current studies do provide evidence of succession in deserts (Webb et al. 1987; Castellanos et al. 2005). This study provides more information on this often overlooked subject.

Disturbed substrates provide a starting habitat for succession and the most likely location for a non-native, invasive plant species to establish (Fox and Fox 1986; Hobbs and Huenneke 1992; With 2002). On substrates without floral or faunal communities, invasive species do not have to compete with members of an established community (interference). Instead, invasive species may acquire resources more rapidly or more completely than native species, thereby preventing other plants from establishing. Invasive species may also directly affect natives (exploitation) (Keddy 1989). Soil nutrient loss is often a result of disturbance. Invasive species may more readily establish in areas with low nutrient availability compared to native species. However, invasive species can invade nutrient rich habitats (Hobbs 1989; Schlesinger et al. 1996), which suggests competition for space as opposed to nutrients. Invasion of nutrient rich habitats implies different mechanisms than the invasion of a relatively nutrient poor habitat.

Invasive plant species can have numerous impacts on native plant species ranging from competition to facilitation. Competition between invasive and native species can occur in a number of ways. The invasive *Salsola tragus*, for example, is a shrubby plant that can trap the seeds of surrounding native plants, thereby preventing them from reaching the soil and germinating (Day and Wright 1989; Vanier and Walker 1999). The invasive trees *Tamarix ramosissima* and *T. aphylla* create a highly saline environment by concentrating salt in their leaves, which they later drop (Berry 1970; Kleinkopf and Wallace 1974). The resultant leaf litter causes an increase in the salt concentration of the soil, preventing the establishment of less salt-tolerant plants (Walker et al. 2006). Brooks (1998, 2000) showed that the invasive species *T. ramosissima* and *Schismus arabicus* exhibit a negative correlation with native annuals.

The negative competitive impact of invasive annual grasses has received much attention in the literature (Bakker and Wilson 2001). However, invasive annual forbs may also have impacts on the system they invade. *Brassica tournefortii* was introduced to the US in the 1920's but has only become of significant concern within the last ten years due to a rapid explosion in population numbers. This raises the question of what was keeping the population under control until just recently. While some indications point toward the recent drought (the start of the drought roughly coincides with the beginning of the population explosion), the Southwest has experienced numerous periods of drought since the arrival of *B. tournefortii*. Is there a fundamental difference in the recent drought compared to previous droughts or is there some other factor affecting the population explosion? While it may be too late to stop *B. tournefortii* from invading in much of the Southwest, my research may provide insights necessary to help prevent any further population explosions of this species.

This study will address several core issues of invasive plant biology. Namely, where are invasive plant species most likely to invade (established areas versus disturbed areas) and what impact does the invasion of an annual forb have not only on other annuals but also on perennial species? *Brassica tournefortii* is apparently not hindered by established communities with regard to its ability to invade, yet it also invades the disturbed areas (S. Gayvert, pers. obs.). I will compare the relative propensity for *B. tournefortii* to invade disturbed communities versus established communities. In addition, field observations also indicate lowered overall diversity of all plants in areas invaded by *B. tournefortii* (Gayvert, pers. obs.).

This study additionally focuses on succession in a desert system. The debate over the occurrence of succession in desert systems results in a need for more studies in order to determine if succession occurs. This study also examines the potential impacts of invasive species on succession. We need to understand the impacts invasive species have on community composition, as invasions become more common worldwide. And, because one of the most common places to find invasive species is in disturbed habitats, we need to gain a better understanding of how invasive species may alter subsequent succession.

CHAPTER 2

COLONIZATION PATTERNS IN THE DRAWDOWN ZONE OF LAKE MEAD

Introduction

Disturbance, invasion and Lake Mead

Global climate change and human activities have made invasive species one of the greatest threats to biodiversity and ecosystem function (Dukes and Mooney 1999; Ziska et al. 2005; Rull and Vegas-Vilarrubia 2006). Invasive species are capable of altering, among other things, the natural succession of systems following disturbance (Vitousek and Walker 1989; Walker and Vitousek 1991; Vitousek et al. 1996). Invasive species can prevent native species from germinating or from successfully completing their life cycles by competing with natives for soil nutrients and space (Beatley 1966; Brooks 2000; Burgess et al. 1991; Hunter 1991). We need to understand the structure and function of the native community in the absence of the invasive species in order to understand how the invasive species altered the community when present.

Drawdown zones, created by the removal of a dam or through natural or man-made fluctuations in water levels, present a unique habitat for succession of native plant species, as well as the introduction and subsequent invasion of non-native species (Paveglio and Kilbride 2000). In the last two decades, over 500 dams have been removed in the US alone (Stanley and Doyle 2003). The removal of a dam permanently lowers the water level of the reservoir. In contrast, drawdown zones created by annual water releases or decadal scale droughts are not permanent. The relative colonization success of invasive versus native species will depend on such factors as the narrowness of the drawdown zone and dispersal patterns (DiVittorio et al. 2007). In deserts, the mesic conditions associated with drawdown zones can provide opportunities for invasion (Busch and Smith 1995; Svejcar and Tausch 1991). Successful invasive plants can reduce native species diversity (Chornesky and Randall 2003) and sometimes invasives spread into established plant communities outside the drawdown zone.

Lake Mead is a reservoir in the northeastern Mojave Desert, created by the completion of Hoover Dam in 1935. The lake is contained within the boundary of Lake Mead National Recreation Area (LMNRA). During the recent drought (year 2000 – 2005), the water level of Lake Mead dropped 27.4 m (Figure 2-1) and the length of the shoreline of Lake Mead was reduced from 1280 km to only 800 km. Not only does this drop in water level provide an opportunity to study succession but, as Lake Mead periodically experiences droughts resulting in drawdown, the study of plant invasion and succession will provide valuable information that may be used to prevent the spread of invasive species around Lake Mead in the future, as well as in other desert and reservoir systems.

Preliminary observations at LMNRA suggest that a mix of native and non-native species colonizes this drawdown zone. Rare native plants such as *Eriogonum viscidulum, Astragalus geyeri* and *Arctomecon californica* have been found in the first year of colonization in the drawdown (E. Powell, pers. comm.). Non-native invasive species such as *Tamarix ramosissima, Tamarix aphylla* and *Salsola tragus* are also present very early in the colonization process, and generally replace the natives within one to two years after establishment. Further from the shoreline, other invasive non-native plants, including *B. tournefortii* and *Schismus arabicus* can form dense stands that appear to exclude many other native and non-native species (Gayvert, pers. obs.).

Brassica tournefortii was probably originally introduced into the southwestern United States from North Africa and the Middle East – most likely coming in with date palms in the 1920's – but this introduction has remained relatively innocuous for the last 70-80 years (Minnich and Sanders 2000). Most introduced species experience a lag phase; many will disappear during this time, but a few will experience a population explosion and become invasive (Hastings 1996). *Brassica tournefortii* has exhibited a population explosion within the last decade (Malusa et al. 2003), which may have potential impacts on native species and ecosystem processes (Trader et al. 2006). For example, the invasion of *B. tournefortii* has decreased available habitat for the endangered Coachella Valley fringe-toed lizard which has extremely restrictive habitat requirements (Barrows 2005).

Another impact of *B. tournefortii* has been the reduction of annual plant species density and percent cover in the Coachella Valley (Barrows 2005). Whether this decrease in native plant species density and cover is caused by direct competition is unknown (Minnich and Sanders 2000). The ability of *B. tournefortii* to invade a stable community and the potential for a population explosion, is a serious threat to both stable desert communities and disturbed habitats such as the drawdown zone of Lake Mead. This study addresses four aspects of the invasion of *B. tournefortii* and *T. ramosissima*, and colonization of these invasive plant species in the Lake Mead drawdown zone.

Objectives

The first objective of this study was to provide an assessment of establishment patterns of both native and non-native plants in the drawdown zone of Lake Mead. By understanding these patterns, park managers may be able to predict how plant communities will develop following future disturbances. Certain plants may be indicator species, meaning that if a plant is growing in a certain area, then there is also a predictable suite of associated species. Links between soil or substrate type and invasive plant species may also allow park managers to predict in which areas they need to focus their control efforts. To this end, soil samples were analyzed to determine if there were any correlations between native and non-native plant establishment patterns and soil parameters of particle size, nitrogen, phosphorus, organic matter, and pH.

A second objective of this study was to examine succession and community assembly in a desert ecosystem. The study of succession, the process of sequential colonization by various plant species on disturbed substrates (Connell and Slatyer 1977; Walker and del Moral 2003), provides information on both the structure and composition of a community. There is debate as to whether succession even occurs in deserts (Goldberg and Turner 1986; Turner 1990; Bowers and Turner 2001, 2002). The study area I chose is of particular interest because it is located at the interface of a desert system and a lake – two systems that are not very often linked. The drawdown zone of Lake Mead is transient because the lake levels are projected to rise again. Therefore, studies performed now may inform management of what to expect in future drawdowns.

Third, this study focused on the impacts of invasive species on desert ecosystems, which are becomingly increasingly important (Gurevith et al 2002). As invasive species spread, we need to understand the impacts on succession and community composition (Humphrey and Schupp 2003) to effectively manage these communities and minimize impacts. The negative impact of invasive annual grasses on desert ecosystems has received much attention in the literature (Evans et al. 2001; Rafferty and Young 2002; Belnap et al. 2005). However, it is also important to focus on how invasive annual forbs impact ecosystems (Dukes 2002). This study examined the impact of a particular invasive annual forb, *B. tournefortii*, on a desert drawdown community at Lake Mead in the Mojave Desert. We need a solid understanding of the interactions of native and non-native species (Bazzaz 1979, 1996; Tilman 1987, 1988) to effectively manage invasive species in natural areas. Field observations indicate that *B. tournefortii* is able to invade both disturbed and established communities. The wide distribution of *B. tournefortii* at Lake Mead NRA allowed comparison of species composition between invasions in disturbed versus established communities.

Finally, this study will help define management decisions for Lake Mead by identifying associations among plant species (both native and invasive) and between plants and their physical environment (soil characteristics, shoreline structure, and elevation). I will not directly address myriad additional concerns, such as links between plants and rare animals (e.g., *T. ramosissima* and the southwestern willow flycatcher; Sogge et al. 2003). However, this study will provide a critical first step in developing a view of this complex ecosystem through an evaluation of colonization in the drawdown zone by both native and non-native, invasive species.

Research questions

1) Are successional patterns evident in the drawdown zone?

Hypothesis 1: Plant community structure will change with time, depending on the years of surface exposure.

a) In the first year after drawdown occurs, total plant cover will not exceed 25% and will be predominantly annual plants and grasses.
b) In the second year, total plant cover will be between 25-50% and plant communities will be a mix of annuals with increasing presence of more stable plants (woody species and suffrutescents that are perennial subshrubs).
c) In the third year, total cover will be >50% and annual species will significantly decline in cover.
d) In the fourth year, the shrubs and grasses will dominate and total plant cover will be >50%.

The first year of succession is generally dominated by pioneer species that are able to establish in a wide range of conditions. As succession progresses, the pioneers are usually sequentially replaced by more stable plant communities as the environment is altered (Connell & Slatyer 1977). The presence of invasive species may change this natural trajectory (Vitousek et al. 1996); however, the first species to establish are still expected to be species that are capable of surviving in a nutrient-poor environment (pioneer species or ruderals) as are many species that are strong invaders, such as *T. ramosissima* and *S. tragus.*

2) What role do invasive species have in colonization of the drawdown zone?

Hypothesis 2: *Brassica tournefortii* and *T. ramosissima* will exhibit greater cover in the drawdown zone than in the established communities.

Hypothesis 3: *Brassica tournefortii* and *T. ramosissima* will interfere with the detection of patterns in colonization.

Invasive species commonly colonize disturbed habitats where there is less competition from stable communities (Eserink 2000). The drawdown at Lake Mead has exposed sections of land that have not been inhabited by plants for at least a decade. This presents an ideal opportunity for invasive plants to establish in the open habitat and alter the natural trajectory of succession. This study will examine the potential impacts of two predominant invasive species, *B. tournefortii* and *T. ramosissima*, on colonization.

3) Does shoreline structure impact colonization patterns of the drawdown zone?

Hypothesis 4: Concave shorelines will exhibit higher cover of native species, *Brassica tournefortii* and *T. ramosissima* than convex shorelines.

On reclaimed mine surfaces areas with concave boundaries or coves were colonized faster than areas with straight or convex boundaries (Hardt and Forman 1989). In terrestrial habitats, concave boundaries provide a shorter distance for seeds to be dispersed, higher rates of entrapment of seeds dispersed by either wind or water and a greater accumulation of organic matter. Additionally, in a shoreline system, concave shorelines provide coves to which seeds may be blown and trapped. As a result, I expect that there will be increases in cover on transects with concave shorelines compared to convex ones.

4) Do soil particle size, organic matter content, pH, and nitrogen play a role in colonization patterns of the drawdown zone?

Hypothesis 5: Soil characteristics (particle size, organic matter, pH, and nitrogen) will impact the development of plant communities.

Different plants require different soil textures to survive, owing partially to varying water availability requirements, which are affected by soil particle size. For example, while many species native to the Lake Mead area have adapted to living on sand dunes, where the substrate is unstable, many invasive species are unable to survive on such unstable surfaces (Hodgkin 1984). However, sand dunes may prove to be home to more invasives than natives because sand dunes undergo frequent disturbances that disrupt the community structure and provide opportunities for invasion. Traditional successional theory states that the first plants to establish will alter the soil chemistry in a way that makes the soil more suitable for other plants (Switzer et al. 1979; Walker and Chapin 1986). Therefore, if succession is occurring, I expect to see changes over time in the measured soil characteristics.

Methods

Design and data collection

I surveyed the drawdown zone of Lake Mead between February 2005 and May 2005. I used topographic maps and selected sections of Lake Mead that had exposed regions of the shoreline with a slope of less than 30 degrees. One transect was randomly chosen within these sections for every 2 km of shoreline for a total of 40 transects. The locations of the transects were: six transects on the north shore of Boulder Basin; seven on the northwest shore of Overton Arm – six south of Overton Beach and 1 North; six on the east shore of Overton Arm, across and north of Echo Bay; eight on the east shore of Overton Arm, across and south of Echo Bay but north of Walker Point; three across from Temple Bar; three at Temple Bar – one east and two west of Temple Bar; three in Bonelli

Bay; and four on the Southeast shore of Boulder Beach – north and south of Burro Point (Figure 2-2; Table 2-1; Appendix B).

Along each transect running perpendicular to the general shoreline, I established five 5.64 m-radius (100 m^2 area) circular plots at five elevations (373.6 m, 369.4 m, 362.4 m, 354.9 m, and 350.9 m a.s.l) representing water levels in January 2001, 2002, 2003, 2004, and 2005, respectively. Additionally, I surveyed two plots on each transect outside the drawdown zone to provide a comparison of the community prior to the drawdown (Figure 2-3). Plot 6 was centered 20 m from the edge of the drawdown zone (a clearly visible boundary) and Plot 7 was centered 20 m past the center of plot 6. A distance of 20 m was chosen to ensure that neither plot would overlap another (8.72 m between edges of each plot) while keeping all plots relatively close to the drawdown zone (<50 m). One week into the surveys, the water level of the lake rose and covered plot 1 for the remainder of the survey period; therefore, no data is reported for this plot. A total of 16,000 m^2 was sampled inside the drawdown zone and 8,000 m^2 outside the drawdown zone. Along each transect I measured physical site variables including slope, aspect, direction and shoreline structure (concave or coves vs. convex or outcrops). I also measured physical site variables in each plot and percent of rock cover by rock type (gravel, cobble, and boulder; Appendix C).

Within each plot, I measured size of each plant greater than 10 cm tall (height and cross-sectional diameter – the longest diameter and its perpendicular), percent cover by species, and percent cover by plant group (annual, grass, woody, suffrutescents, bryophytes, and total) for all plants. Percent cover was estimated using cover classes (+: <1%; 1: 1-5%; 2: 6-25%; 3: 26-50%; 4: 51-75%; 5: 76-95%; 6: 96-100%). For any plants that I was unable to identify in the field, I collected a digital picture for later identification. Any plants less than 10 cm tall were not measured individually but were included in estimates of species cover and plant group cover and were included in the overall species list.

After 5 transects were surveyed (12.5% of all transects), a correlation showed that height and diameter were highly correlated for *B. tournefortii*, *Eriogonum deflexum*, and *T. ramosissima*. Therefore, because these three species were highly dominant in the drawdown zone, I decided to measure each of the three species using classes. I created the following classes for each of the species. For *T. ramosissima* and *B. tournefortii,* the classes were based on height and for *E. deflexum* classes were based on the plant canopy diameter: *T. ramosissima* height classes: T1 – 10-50 cm, T2 – 50-100 cm, T3 – 100-200 cm, and T4 – 200+ cm; *B. tournefortii* height classes: B1 – 10-30 cm, B2 – 30-50 cm, B3 – 50-100 cm, and B4 – 100+ cm; and *E. deflexum* cover classes: E1 – 10-30 cm, E2 – 30-50 cm, E3 – 50-100 cm, and E4 – 100+ cm. Classes were determined by visual inspection of the data and where breaks tended to fall.

In addition, I collected 20 g of soil at five points (the center and the north, south, east and west points) within each plot. Soil was filtered through a 2mm sieve then air-dried for 48 hours. The dry soils were analyzed for pH, organic matter content and particle size. Soil pH was determined by mixing 5g of soil with 5ml of distilled water. The pH of the solution was then measured using a glass probe pH meter (McLean 1982). Organic matter (% loss on ignition) was calculated from soil samples that were dried overnight at 105°C and mass loss was measured at 550°C (Karem 1993). Soil particle size (percent sand, silt and clay) was determined by using a hydrometer to determine the specific gravity of a solution of 40 g soil (dried overnight at 40°C) in 1L water (Sheldrick and Wang 1993). To analyze total nitrogen and phosphorus of the soil samples, 0.600mg of soil was digested using sulfuric acid and mercuric oxide solution. The extractions were stored in scintillation vials in a freezer until analysis began. The extracted solutions were analyzed colorimetrically with an Alpkem Segmented Flow Analyzer for total Kjeldahl N (Alpkem Corporation, 1992).

Data analysis

Chi-square analysis was used to compare a) total cover and cover by plant group among all plots; b) the cover of non-native species in the drawdown zone and in the established communities; c) plant cover in concave and convex shorelines; and d) native annual presence and other plant groups among different substrates (Pallant 2007). Analysis of total cover by group (comparison a) was completed after the removal of all plots with greater than 25% cover of invasive species. Additionally, chi-square analysis for trend was used to reanalyze the comparison of total cover and cover by plant group. Chi-square analysis was used to compare the invasion of *B. tournefortii* and *T. ramosissima* on concave versus convex shorelines. Also, we used the total number of species in each plot to determine the number of species per 100 m^2 and averaged across all 40 plots for each water level. This data was then analyzed with a one-way ANOVA (Pallant 2007) in order to determine if there were changes in the mean number of species over time.

MANOVA was used to analyze the organic matter content, pH, particle size, and nitrogen as well as slope and aspect of each plot. Physical site characteristics (organic matter content, pH, particle size, nitrogen, slope, aspect, and percentage of rock cover) were used in a cross-tabs analysis to separate transects into groups based on similar characteristics. Cover classes (comparison a) were then reanalyzed within these groupings (Pallant 2007). An $\alpha < 0.05$ was used for all tests.

Results

Successional patterns

Across all plots, significant patterns were detected in cover of annuals, grasses and woody species, as well as total cover (annuals: $\chi_{35}^2=65$, $p<0.01$; grasses: $\chi_{35}^2=103$, $p<0.001$; woody: $\chi_{35}^2=90$, $p<0.001$; total: $\chi_{35}^2=113$, $p<0.001$; plant cover class data is shown in Appendix D and complete species list in Appendix E). There were no detectable patterns in the distribution of bryophytes or suffrutescents (bryophytes: $\chi_{35}^2=14$, $p=0.999$; suffrutescents: $\chi_{35}^2=24$, $p=0.915$). Established communities had significantly higher cover of all plant groups (Figure 2-4).

Analyzing percent cover without plots 6 and 7 (established communities) resulted in non-significant results for all plant groups within just the drawdown zone (annuals: $\chi_{21}^2=24$, $p=0.312$; grasses: $\chi_{21}^2=13$, $p=0.902$; woody: $\chi_{21}^2=25$, $p=0.223$; total: $\chi_{21}^2=13$, $p=0.897$). Therefore, it appeared that the previously significant results were due to the difference between the drawdown zone as a whole compared to the established communities. The trend analysis showed the same pattern. While no evidence of succession within the last 4 years was found in this test, there were a few interesting patterns. Annual cover increased with time of exposure despite expectations for annuals to be gradually replaced by more stable woody species; woody species were present in consistently low levels throughout the drawdown zone, with the exception of plot 2

(Figure 2-4). Additionally, total cover remained relatively consistent within the drawdown zone as opposed to the expected increase with time of exposure. Mean number of species per 100 m^2 showed an overall increase per plot as distance to the shoreline increased ($p<0.001$; Figure 2-5).

Colonization by invasive species

Field surveys showed that *T. ramosissima* invasion was greatest closest to the current shoreline and generally decreased with increased distance from the water ($\chi_5^2=12.89$, $p<0.05$; Figure 2-6). Conversely, the presence of *B. tournefortii* was consistent across all plots independent of distance to the shoreline ($\chi_5^2=1.00$, $p=0.963$; Figure 2-6). Overall, out of 240 total plots surveyed, *T. ramosissima* was present in more plots (95%) than *B. tournefortii* (37.5%). If the cover of *B. tournefortii* or *T. ramosissima* was greater than 25% in any one plot, the plot was considered to be dominated by that species. *Tamarix ramosissima* was dominant in only 2.5% of plots surveyed and these plots were all the closest to the shoreline (plot 2). *Brassica tournefortii* was only dominant in 1.25% of all plots, all of which were plot 2.

Overall, the *T. ramosissima* invasion was characterized by dense thickets of individuals near the water's edge. As the distance to the shoreline increased, the number of individuals decreased (876 individuals in plot 2 compared to 271 individuals in plot 5 ($\chi_{15}^2=221.05$, $p<0.001$; Figure 2-7). Interestingly, there appeared to be high mortality of *T. ramosissima* after the first year (876 individuals was reduced to 162 individuals from plot 2 (2004) to plot 3 (2003), followed by a gradual increase of individuals and then another decline of individuals in plot 6 ($\chi_{15}^2=352.33$, $p<0.001$; Figure 2-7). In contrast, although *B. tournefortii* is also found in dense thickets more commonly in the drawdown zone (thickets are found in established communities as well), average size does not vary significantly except for a decrease in number in Plot 5. The increases and decreases in number of individuals may be due to a number of factors including water level variations during germination (declines in water level during germination may result in an unsuitable environment for germination), potential competitive interactions from other species, and many others. Further research is necessary to fully understand the causes of the changes in establishment patterns during different years.

To determine if the dominant presence of invasive species could be masking the detection of successional patterns in cover for native species, the analyses were all performed an additional time after removing plots with a dominant cover (>25%) of either *T. ramosissima* or *B. tournefortii*. When analyzed across all plots, the results mirror those prior to the removal of plots with dominant invasive cover. Annuals, grasses, woody species and total cover for native species were all significant across all plots (annuals: $\chi_{35}^2=56$, $p<0.05$; grasses: $\chi_{35}^2=94$, $p<0.001$; woody: $\chi_{35}^2=107$, $p<0.001$; total: $\chi_{35}^2=107$, $p<0.001$) while bryophytes and suffrutescents were not significant (Figure 2-8). The inability to detect successional patterns following the removal of plots dominated by *B. tournefortii* and *T. ramosissima* indicates these two dominant invasives were not masking successional patterns.

Shoreline structure and colonization patterns

Transects were divided based on shoreline structure with 25 on concave and 15 on convex shorelines. The two shoreline structures do not exhibit the same patterns in plant groups across all plots and all plant groups (annuals: $\chi_{35}^2=139$, $p<0.001$; grasses: $\chi_{35}^2=106$, $p<0.001$; woody: $\chi_{35}^2=112$, $p<0.001$; bryophytes: $\chi_{35}^2=59$, $p<0.01$;

suffrutescents: $\chi_{35}^2=65$, $p<0.01$; total: $\chi_{35}^2=117$, $p<0.001$). Concave shorelines exhibited consistent cover by plant groups across the drawdown zone with an increase in the established zone (Figure 2-9). Convex shorelines, in contrast, exhibited variable patterns of cover by plant group. The cover of woody species was highest close to the shore and then cover decreased before increasing again in plot 5 and in the established zone 6. The cover of annual species, however, was low closest to the water and gradually increased in cover in older plots and in the established zone (zone 6). Grasses cover averaged < 1% throughout the drawdown zone but increased to 26-50% in the established zone.

Invasion patterns also differed on convex as contrasted to concave shorelines. *Brassica tournefortii* was significantly more prevalent on concave shorelines than on convex ones ($\chi_{15}^2=504.64$, $p<0.001$; Figure 2-9). However, *B. tournefortii* showed a relatively consistent pattern in transects placed in each shoreline shape, but in fewer numbers than on the convex shorelines. *Tamarix ramosissima*, on the other hand, also exhibited significantly different patterns on the two shorelines ($\chi_{15}^2=623.79$, $p<0.001$; Figure 2-10). On concave shorelines, *T. ramosissima* began high in number and then dropped and remained relatively stable across all plots (including the drawdown zone and the established community). On convex shorelines, *T. ramosissima* started off high in number (although lower than on concave), followed by a drop in plot 3 then a gradual increase through 4 and 5, with another drop in 6 and a small presence in 7.

Soil characteristics and colonization patterns

The analysis of the soil data showed no significant change over time of the soil parameters (averages shown in Table 2-2). Initially, a MANOVA was performed on all the data (particle size, pH, organic matter content, and nitrogen) using plot, slope and aspect (Appendix F) as predictors of patterns in soil characteristics (see Appendices G and H for raw data). This analysis yielded no significant results. Results that followed cross tabs categorization also yielded no significant patterns.

While the soil data yielded no significant results, there were several interesting trends. For example, soil pH tended to increase with distance to the shoreline within the drawdown zone but tended to decrease in the established community. Soil organic content tended to increase in the established community compared to the drawdown zone. Also, the drawdown zone tended to be higher in sand content than the established community and the established community tended to be higher in clay content than the drawdown zone. Furthermore, nitrogen levels tended to be higher in the established community than in the drawdown zone (Table 2-2).

Discussion

Succession

The field surveys of Lake Mead's drawdown zone did not reveal any clear successional patterns; however, several interesting aspects of invasive species and their potential impacts on community development were evident. If the plots were resurveyed in the future, the additional data might show evidence of successional patterns. Colonization in the desert occurs more slowly than in many other habitats (Hanes 1971). Over the course of a longer study, successional patterns may become evident (Webb et al. 1987). Although this study did not show evidence of succession through replacement of plant groups, there was a significant increase in the number of species per plot with time. This accumulation of species over time indicates some form of succession is occurring and perhaps additional follow-up studies would show patterns in colonization we were unable to uncover during this study.

Additionally, no evidence was found of invasive species' dominance masking successional patterns. Although *T. ramosissima* is one of the most widespread and influential invasive species in the Southwest, *B. tournefortii* presented an intriguing contrast. *Tamarix ramosissima* was found predominantly close to the shore and on flatter slopes. *Brassica tournefortii*, on the other hand, was evenly represented throughout both the drawdown zone plots and into the established communities. Therefore, *B tournefortii* is potentially of equal concern to *T. ramosissima* due to *B. tournefortii*'s ability to invade beyond the floodplain (Minnich and Sanders 2000).

Invasion patterns

The highest percent cover of *T. ramosissima* tended to be closest to the shoreline, with the largest plants located furthest from the shoreline within the drawdown zone. Virtually every *T. ramosissima* found in the plots closest to the water level had a stem diameter of less than 2 cm. Nearest the shoreline, *T. ramosissima* grew in very dense thickets of tall, thin individuals. However, in the plots furthest from the shoreline, but still within the drawdown zone, there were generally only a few individual plants in the plots. However, in these drawdown zone plots, *T. ramosissima* plants all had canopy diameters greater than 2 m. The decrease in number of individuals with an increase in size of each individual suggests that intraspecific competition may be occurring (Wiegand et al. 2008).

Species richness declines in habitats invaded by non-native species (Meiners et al. 2001). This study shows that invasive species do not appear to be completely out-competing the native species during the first year of succession. Both native and invasive plants are present in the initial stages of succession. Competition is one of the driving forces behind succession, especially in arid regions (Fowler 1986) as shown by *T. ramosissima* (Busch and Smith 1995). Another mechanism driving succession is facilitation, during which the presence of a particular plant in an area aids the growth of other plants. For example, although *T. ramosissima* creates a high saline environment that is unfavorable to most native plant species (DiTomaso 1998), this study provides evidence that *B. tournefortii* has both competitive and facultative relationships with native plant species (Chapter 3).

Shoreline structure

The comparison of convex versus concave shorelines resulted in a few interesting differences. Walker et al. (2006) found preferential establishment during primary succession on concave terrestrial microsites in a New Zealand floodplain. However, in this study, the convex shorelines exhibited higher total plant cover than the concave ones. Instead of seeds floating into the coves and being trapped, it appeared that the seeds are carried past the concave shorelines and caught on the land extending out in the convex shorelines. Slope may also explain cover data. In general, the slope of convex shorelines tended (non-significantly) to be steeper than slopes of the concave shorelines. This is contrary to other research in which higher slopes lead to decreased soil fertility (Bennie et al. 2006). Perhaps additional research would uncover a characteristic I failed to measure that will explain this anomaly.

Woody species had greater cover on convex shorelines and annuals had higher cover on concave shorelines. However, annual cover on concave shorelines was the same in all the drawdown zone plots, but increased over time in the convex shorelines plots. Woody species on the convex shorelines were high in number near the shoreline and then decreased over time and distance from shoreline. Both of these trends are contrary to what would be expected from the facilitation model of successional theory (Walker and Chapin 1986). In this model, the less stable (shorter-lived), annual species would be expected to colonize initially. These colonizing annuals would alter the environment in ways that would facilitate the establishment of other species leading to changes in community composition over time.

Soil characteristics

The establishment patterns of plants may be affected by water, nitrogen, and phosphorus availability; no evidence of this effect was seen in this study. Nitrogen and water are two of the most critical resources for which plants compete in the Mojave Desert (Rundel and Gibson 1996), with phosphorus a close third. Interestingly, in this study, I found no evidence of soil nitrogen playing a role in colonization patterns. While phosphorus was not analyzed, the Boulder Basin of Lake Mead is home to the inflow from the Las Vegas Wash which is very high in phosphorus (Adams and Prentki 1986). However, there were no differences in establishment patterns in the neighborhood of the Las Vegas Wash compared to elsewhere around the lake. The ability of some non-natives, like *T. ramosissima*, to utilize large quantities of water resources from deep water sources (Sala et al. 1996) may be a more important factor in their success. An examination of soil characteristics (slope, aspect, rock composition – all of which can affect water availability) still did not yield any evidence of successional patterns in this study. Therefore, although these soil characteristics probably affect colonization, they did not appear to affect succession in this study.

Conclusion

No evidence was found in this short-term study of any successional patterns. In fact, many of the observations were contrary to what would be expected in a successional system. However, these results could be affected by the inclusion of invasive species in cover estimates. While I did attempt to correct for this in analysis by removing plots dominated by the two most common invasive species in this system, additional studies may yield further insights. A study of transects invaded only by one of each of the two dominant invasive species as well as transects in which neither invasive is present would be ideal.

Brassica tournefortii does not appear to be inhibited in its invasion by established communities, as are many other invasive species. Is this ability to invade in any habitat due to *B. tournefortii*'s early germination or due to some other intrinsic factor? Does *B. tournefortii* out-compete native species for resources and space? Is it merely because *B. tournefortii* is capable of producing massive amounts of viable seeds every year such that the natives are overwhelmed by shear numbers? Whatever the reason for the success of *B. tournefortii*, it is clear that the species requires further investigation.

CHAPTER 3

COMPETITION BETWEEN *BRASSICA TOURNEFORTII* AND FOUR NATIVE SPECIES

Introduction

Invasive species are one of the greatest threats to biodiversity (Williamson 1999; Jenkins and Pimm 2003; Sanders et al. 2003). Invasive species have a variety of negative impacts on communities. For example, invasive plants are capable of altering the natural succession of ecosystems following disturbance through competition with native species (Holdaway and Sparrow 2006). There are numerous methods by which invasive species are capable of competing such as through more efficient nutrient acquisition than native species. *Tamarix ramosissima* can rapidly produce an elongated taproot that has an ability to acquire water faster than natives (DiTomaso 1998). Invasive species can acquire resources earlier in the season than natives; a process known as pre-emption of resources (Huang et al. 2008). An invasive plant that can germinate earlier than natives has an advantage in resource acquisition, including the acquisition of space and the resources related to that space (Britton-Simmons 2006).

Sagar (1959 [cited in Harper 1977]) and Ross and Harper (1972) showed that differences in germination time, which correlate to differences in relative sizes of two competing species, are a highly significant factor in determining which species is going to out-compete the other. One well documented example of the advantage of early germination is *Bromus tectorum*. *Bromus tectorum*, an invasive grass species in the Mojave Desert, is a successful invader of disturbed habitats due to its ability to germinate earlier than native species (Aguirre and Johnson 1991; Pyke and Novak 1994). However, if there is no disturbance to open habitat, the stable community is often able to resist invasion (Cline et al. 1977).

It is possible that the successful invasion of *Brassica tournefortii* in the southwest is due to its ability to germinate earlier than native desert plant species (Trader et al. 2006). By the time native species begin to grow, *B. tournefortii* may have already occupied most of the space and absorbed the available nutrients, leaving little for the native plants. *Brassica tournefortii* typically germinates in January and early February, which is earlier than many native annuals.

In this study, I focused on the impact of the invasive annual *B. tournefortii* on the native community by testing the impact of germination time on biomass allocation between *B. tournefortii* and four native annual plant species. *Camissonia claviformis* (Torrey and Fremont) is an annual native common to the Mojave Desert and a member of the primrose family. *Geraea canescens* (Torr. and Gray), also known as the Desert Sunflower, is a common annual species that acts as a short-lived perennial in some environments. *Geraea canescens* will occasionally experience more than one flowering season, something also seen with *B. tournefortii*. *Lupinus arizonicus* (S. Watson) is a common annual species native to the Mojave and Sonoran Deserts, abundant even in years of low rainfall. *L. arizonicus* also shows evidence of high drought tolerance; both characteristics are shared by *B. tournefortii*. *Sphaeralcea ambigua* (Gray) is a common perennial suffrutescent found widespread throughout the deserts of the southwestern US and into Sonora, Mexico (MacKay 2003). *Sphaeralcea ambigua* is often found growing in similar microhabitats as *B. tournefortii* but the two species were rarely found near each other (pers. obs. 2005). I used a greenhouse experiment to examine the interaction between *B. tournefortii* and these species through alteration of germination order and the potential for each species to pre-empt resources. The use of a greenhouse for this experiment allows environmental control not available in the field, thus ensuring that the variables being tested are the only factors affecting the outcome of the experiment (Callaway et al. 1999).

Research questions

1) What is the impact of order of germination on competition between *B. tournefortii* and native species?

   <u>Hypothesis 1:</u> When germinated and sown 4 weeks prior to a native species, *B. tournefortii* will exhibit an increased biomass (both aboveground and belowground) in comparison to other treatments.

   <u>Hypothesis 2:</u> When germinated and sown at the same time as a native species, the aboveground and belowground biomass of *B. tournefortii* will not be significantly different from those germinated and sown at different times.

   <u>Hypothesis 3:</u> When germinated and sown 4 weeks after a native species, *B. tournefortii* will exhibit a decreased biomass (both aboveground and belowground) in comparison to individuals germinated at the same time or prior to the native species.

Methods

Each of four native species, *C. claviformis*, *G. canescens*, *L. arizonicus*, and *S. ambigua*, were grown separately in a 20 L pot with *B. tournefortii* in one of three possible treatments, with 10 replicates of each combination of *B. tournefortii* and each native species per treatment, for a total of 120 pots. Pots were placed randomly within the greenhouse and rotated biweekly to prevent location effects. Each 20 L pot was filled with potting soil and watered daily for one week prior to the start of the experiment to ensure complete saturation of the soil. In addition, each pot was treated with 2 tablespoons of NPK fertilizer (Brand: Dr Q's Triple Play Lawn and Plant Fertilizer 7-7-7) prior to the start of the experiment.

All seeds used in the experiment were germinated in Petri dishes for 48 hours prior to being sown. *Brassica tournefortii*, *G. canescens*, *L. arizonicus*, and *S. ambigua* were all germinated at room temperature while *C. claviformis* required 12 hours of cold treatment prior to germination. Germinated seeds were then arbitrarily selected and sown into pots. Five germinants of each species with 1 cm long radicals were sown in the pots. Pots were thinned to one individual of each species one week after sowing. In the first treatment (T1), *B. tournefortii* was sown four weeks prior to the native species. After four weeks of *B. tournefortii* growing alone, the germinants of the competing species were sown in the same pot. The individual of each species then grew together for eight additional weeks. In the second treatment (T2), *B. tournefortii* and the native species were sown at the same time and the surviving two plants grown together for a total of twelve weeks. In the third treatment (T3), the native species were sown in their respective pots and allowed to grow alone for four weeks. At the end of the four weeks, *B. tournefortii* was sown. The two species grew together in the same pot for an additional eight weeks. At the end of the twelve week growth period, the plants were harvested for measurement of both aboveground and belowground biomass following drying at 40°C to a constant mass.

Data analysis

As all the data met the requirements of normal distribution and equal variance, MANOVA's were used to test the null hypothesis that there is no effect of time of sowing on *B. tournefortii, L. arizonicus, C. clavıformis, G. canescens* and *S. ambigua* biomass allocation. A separate MANOVA was run for each species. For the native species, the independent variables were treatment and growth time, and the dependent variables were aboveground and belowground biomass. The design for *B. tournefortii* was similar, but included the independent variable of which native species it was sown with to determine if there was an effect of native species as well as a treatment effect. The Bonferroni adjustment was used for post-hoc analysis (Pallant 2007).

Results

The MANOVA resulted in an overall significant effect of time of sowing for each species on both aboveground and belowground biomass ($p<0.05$). For both aboveground and belowground biomass of *C. clavıformis*, biomass was significantly lower when sown after *B. tournefortii* was sown (treatment 1) than when sown before *B. tournefortii* was sown (treatment 3) ($p<0.05$ for both aboveground and belowground biomass; Figure 3-1). For *G. canescens*, biomass for both aboveground and belowground was less than when sown at the same time as *B. tournefortii* (treatment 2) or sown before *B. tournefortii* (treatment 3) ($p<0.001$ for both treatments and both aboveground and belowground biomass; Figure 3-2). For *L. arizonicus*, aboveground biomass when sown at the same time as *B. tournefortii* (treatment 1) was significantly lower than when sown before *B. tournefortii* (treatment 3) ($p<0.05$). When *B. tournefortii* was sown before *L. arizonicus* (treatment 1) the aboveground biomass of *L. arizonicus* was lower than when sown before *B. tournefortii* (treatment 3) although the difference was not significant (Figure 3-3). Both the aboveground and belowground biomass of *S. ambigua*, when sown after *B. tournefortii* (treatment 1) was significantly lower than when sown before *B. tournefortii* (treatment 3) ($p<0.01$ for aboveground biomass and $p<0.001$ for belowground) (Figure 3-4).

Brassica tournefortii responded differently when grown with each of the native species (Figure 3-5). When grown with *C. claviformis*, aboveground biomass differed among treatments ($p<0.05$). When sown before or at the same time as *C. claviformis*, biomass was higher for *B. tournefortii*, although not significant. Biomass was significantly lower for *B. tournefortii* when sown after *C. claviformis* ($p<0.001$) than when sown at the same time or before *C. claviformis*. Treatment 2 (sown at same time) resulted in significantly greater aboveground biomass for *B. tournefortii* than treatment 3 (sown after *C. claviformis*) ($p<0.05$) (Figure 3-5a). With respect to belowground biomass for *B. tournefortii*, treatment 1 (sown before *C. claviformis*) was significantly greater than both treatment 2 (sown at same time as *C. claviformis*) and 3 (sown after *C. claviformis*) ($p<0.01$, $p<0.001$, respectively).

When *B. tournefortii* was grown with *G. canescens*, there was strong evidence in support of pre-emptive dependence. Aboveground biomass for *B. tournefortii* was greater in treatment 1 (sown before *G. canescens*) than both treatment 2 (sown at same time as *G. canescens*) and 3 (sown after *G. canescens*) ($p<0.001$ for both treatments). For belowground biomass of *B. tournefortii*, all treatments were significantly different from each other ($p<0.05$ for all treatments). Belowground biomass was the greatest in treatment 1 (sown before *G. canescens*) and the lowest in treatment 3 (sown after *G. canescens*); treatment 2 (sown at same time as *G. canescens*) fell in between (Figure 3-5b).

The response of *B. tournefortii* when grown in competition with *L. arizonicus* was unique among the annual species. Aboveground biomass of *B. tournefortii* (Figure 3-5c) was significantly greater in treatments 1 (sown before *L. arizonicus*) and treatment 2 (sown at same time as *L. arizonicus*) than in treatment 3 (sown after *L. arizonicus*) ($p<0.001$ for both treatments). There was also a non-significant increase of *B. tournefortii* aboveground biomass from treatment 1 (sown before *L. arizonicus*) to treatment 2 (sown at same time as *L. arizonicus*), potentially pointing toward a facultative effect of *L. arizonicus* on *B. tournefortii* when germinated at the same time. Additional studies of this relationship may provide insights into the nature of the relationship and potential management implications for controlling *B. tournefortii* infestation in areas dominated by *L. arizonicus*. For belowground biomass, the average biomass of *B. tournefortii* across treatment 1 (sown before *L. arizonicus*) and treatment 2 (sown at same time as *L. arizonicus*) was actually very close – 0.64 and 0.65, respectively. However, biomass of *B. tournefortii* in treatment 3 (sown after *L. arizonicus*) was significantly lower than both treatments 1 and 2 (sown before and at same time as *L. arizonicus*) ($p<0.05$, $p<0.01$, respectively).

Brassica tournefortii's response to *S. ambigua* - the only perennial species in the experiment - also yielded some interesting results. Aboveground biomass of *B. tournefortii* in treatment 1 (sown before *S. ambigua*) was significantly greater than treatment 3 (sown after *S. ambigua*) ($p<0.05$). Interestingly, however, belowground biomass of *B. tournefortii* showed no significant differences across all three treatments (Figure 3-5d) potentially indicating that *B. tournefortii* may be allocating resources to roots in order to compete with *S. ambigua* rather than to aboveground biomass when sown at the same time and after *S. ambigua*.

Discussion

Invasive species compete with native species in a multitude of ways; invasive species may alter the habitat (allelopathy for example; Callaway and Aschehoug 2000), acquire resources more rapidly or more readily than natives due to release from competitors in native habitat (evolution of increased competitive ability; Blossey and Notzold 1995), and obtain resources before natives (Pysek and Richardson 2007). Early work in resource competition showed that individuals provided with the ability to germinate earlier than other co-existing species generally were larger than other individuals of other species (Ross and Harper 1972). Pre-emption of resources through early germination has since been identified as a competitive advantage for many invasive species (Pysek and Richardson 2007). Further, this ability may enable invasives to move into both disturbed and established communities more quickly than natives (Britton-Simmons 2006; Huston and DeAngelis 1994). When invasive plants establish and germinate before natives in the same habitat, the invasive can garner important resources such as space, nutrients and available water, thereby reducing the competitive ability and growth potential of the native.

Minnich and Sanders (2000) showed that in the Coachella Valley, California, *B. tournefortii* does exhibit earlier germination than most native species, which often flower by early December and set seed in January. The results of the greenhouse experiment support the hypothesis that germination earlier than a native competitor can significantly enhance the growth of *B. tournefortii* as shown by aboveground and below ground biomass. Often, biomass is reallocated from aboveground to below ground biomass or the reverse in response to competition (Aerts et al. 1991). I found evidence of biomass reallocation (decreases in aboveground biomass without corresponding decreases in belowground biomass) in response to competition. *Brassica tournefortii*'s reallocation of resources in response to competition could indicate species which may be able to effectively compete with *B. tournefortii* and potentially be used in management efforts to control *B. tournefortii* populations.

The competitive response of *B. tournefortii* to competition to each of the four native species tested was unique for each native species. When *B. tournefortii* was grown with *C. claviformis*, the decrease in aboveground biomass of *B. tournefortii* could as easily be attributed to either resource pre-emption by *C. claviformis* or to shortened growth time. Based on the decrease in belowground biomass of *B. tournefortii*, however, there does appear to be some competition occurring between *B. tournefortii* and *C. claviformis* and potentially some evidence for biomass reallocation in *B. tournefortii*. Even more interesting, when *B. tournefortii* was sown with *G. canescens*, the species with the most similar characteristics, there was strong evidence to support *B.*

tournefortii's pre-emptive dependence due to the sharp decline in aboveground biomass of *B. tournefortii* when sown at the same time as *G. canescens* compared to when sown before *G. canescens*. In contrast to the other annual species, when *B. tournefortii* was grown with *L. arizonicus*, *B. tournefortii*'s changes in biomass can be attributed solely to growth time (eight weeks vs. twelve weeks) as opposed to a competitive response. Lastly, when *B. tournefortii* was grown with *S. ambigua, B. tournefortii* appeared to reallocate resources belowground. Holzapfel and Mahall (1999) found a positive effect of the shrub *Ambrosia dumosa* on native annuals in the Mojave Desert but a negative effect of annuals on the shrub. More work needs to be done on the interaction between *S. ambigua* and *B. tournefortii* to determine if desert shrubs such as *S. ambigua* may enhance growth of annual invasives such as *B. tournefortii*, but the annual invasive negatively affects growth of shrubs.

As expected, the competitive effect of *B. tournefortii* on the native species is just as varied as the response of *B. tournefortii* to growth with natives (Vila et al. 2004). *Camissonia claviformis* showed no indication of resource allocation and had the highest total biomass (both aboveground and belowground) when sown earlier than *B. tournefortii* compared to when sown at the same time or after *B. tournefortii*. Interestingly, *G. canescens*' response to *B. tournefortii* could be attributed to growth time alone even though competition between *G. canescens* and *B. tournefortii* resulted in the most pronounced decrease in aboveground biomass of *B. tournefortii*. So, for these two species, there was a negligible impact on *G. canescens* but a negative impact on *B. tournefortii* when *G. canescens* was sown at the same time or before *B. tournefortii*. Also, when *B. tournefortii* was grown with *L. arizonicus*, *L. arizonicus* had the lowest mean biomass when sown at the same time as *B. tournefortii.* This is especially interesting because *B. tournefortii* tended to exhibit and increased overall biomass in the same treatment. Although neither of these responses was significant, further research may show significant impacts positive impacts of *L. arizonicus* on *B. tournefortii* and negative effects of *B. tournefortii* on *L. arizonicus*. Lastly, while *B. tournefortii* exhibited signs of resource reallocation in response to *S. ambigua*, *S. ambigua* did not exhibit a similar pattern.

As demonstrated here, competitive effects (effect of one species on another during competition) respond to different variables than competitive responses (response of one species to the competitor during competition). Keddy et al. (1989) found that while competitive effect was related to relative growth rate, competitive response was not and response was relatively consistent even with different neighbors. Further work needs to be done with both the competitive effects and responses of *B. tournefortii* because order of sowing does not explain all of the effects and responses seen in this experiment.

Although most invasive species invade disturbed habitats (Prieur-Richard and Lavorel 2000; Marvier et al. 2004), *B. tournefortii* invaded both disturbed and established communities (Chapter 2). At Lake Mead National Recreation Area, *B. tournefortii* invaded equally the disturbed habitat of the drawdown zone and the established communities (Chapter 2). Early season germination of *B. tournefortii* could be a major factor contributing to the success of this species in both disturbed and established communities. Because *B. tournefortii* germinates earlier in the growing season than native annual species, *B. tournefortii* is not restricted to disturbed habitats where there may be less competition, especially in desert communities. Instead, *B. tournefortii* is able to establish in any open location as long as no annual natives nearby have germinated. More research is necessary to understand the competitive effects and responses of *B. tournefortii* to effectively manage this newly invasive species.

CHAPTER 4

CONCLUSIONS AND MANAGEMENT IMPLICATIONS

Succession and invasion are closely linked processes. Disturbance, the starting point for succession, also provides the ideal habitat for invasive species establishment. Because of the increasing globalization of the world, species are introduced ever more rapidly into new environments where they have the potential to become invasive (Gurevith et al. 2002). According to Williamson's (1996) rule, 10% of all introduced species will establish and 10% of those will become invasive. Additionally, disturbances like landslides, floods and fires are also becoming more common (Kurz et al. 1995). As a result, the study of succession and invasion, as well as their interactions, must become a priority.

The field surveys of Lake Mead did not yield any evidence of significant successional patterns. However, the significant differences found between community compositions within the drawdown zone compared to the established (non-disturbed) community indicate the presence of structured communities. Succession in deserts is considered to be a slow process (Castellanos et al. 2005). A longer term study of Lake Mead's drawdown zone might show successional patterns.

The drawdown zone of Lake Mead is an ideal location for invasion. Most of the land has been under water for 70 years, which resulted in a large expanse of land with no established communities. The lake provides a water source as well as a dispersal route for many seeds, including *B. tournefortii,* which is known to float on Lake Mead and has seeds which survive and germinate following 11 weeks of submersion in water (Bangle et al. in press; Powell, pers. com.). Finally, many areas of the lake are extremely remote, which hampers removal efforts. Invasive species such as *T. ramosissima* specialize in invading riparian habitats and, as seen in Chapter 2, and can remain within the disturbed areas. Other invasive species, such as *B. tournefortii*, will establish readily in the drawdown zone and then gradually invade the established communities. Both of these invasion patterns can have significant impacts on the successional processes that would occur in the absence of invasion.

Although *T. ramosissima* is considered an invasive species of major concern in the Southwest due to its high water use, the field surveys of Lake Mead show that *B. tournefortii* should also be a concern. *Tamarix ramosissima* can prevent other species from establishing by dropping leaves that contain highly concentrated levels of salt (Berry 1970; Kleinkopf and Wallace 1974), potentially decreasing the biodiversity in the invaded habitats. *Brassica tournefortii*, which can also produce dense thickets that prevent other species from establishing (Barrows 2005), invaded disturbed areas and established communities.

The greenhouse experiment showed that *B. tournefortii* negatively impacted the growth of several native species when it was sown prior to the native. In the field, *B. tournefortii* germinated before many of the native species (as early as December if the winter is mild; Minnich and Sanders 2000; Bangle et al. in press). *Brassica tournefortii* can potentially out-compete many native species if it is able to germinate prior to the native species. And, if *B. tournefortii* can successfully germinate, grow and produce seeds prior to native species germinating, the spreading seeds will also be able to germinate and potentially dominate the locations the seeds expand into.

Brassica tournefortii presents several management problems. An individual plant can produce upward of 6000 seeds (Trader et al. 2006). Large individuals at Lake Mead NRA were estimated to have up to 10,000 seeds per plant (Powell, pers. com). Also, the growth cycle of *B. tournefortii* is short enough that, during mild winters, more than one generation may occur in a single year (Barrows 2005). Brooks (2000) also showed that removal of some *B. tournefortii* individuals, but not all, resulted in a population boom due to release from intraspecific competition. As a result, an effective removal technique for *B. tournefortii* is complete removal of all individuals including immature seed heads prior to seed dispersal.

Management and restoration of disturbed and invaded ecosystems presents a unique set of concerns in desert systems compared to other systems. Desert nutrient and water delivery systems are easily damaged, and, due to their water and nutrient limitations prior to disturbance and invasion, are highly complicated to repair (Lovich and Bainbridge 1999; Lovich 2002; Bainbridge 2007). As opposed to other systems, the extreme temperatures, low water availability, and poor soil fertility of deserts can result in 100 or even 1,000 year time spans before conditions are conducive to establishment of certain native species (Bainbridge 2007). Regardless of the system, an essential starting point for successful restoration is an understanding of the process of succession after disturbance (Glenn-Lewin et al. 1992; Walker and del Moral 2003; Walker et al. 2007).

Management of the drawdown zone of Lake Mead presents problems beyond those of a typical desert system. In addition to previously described problems, the drawdown zone has the added challenge of being transitory. Should the lake levels increase and then later decrease again, the information from this study can be used to stay ahead of invasions. Even if the water levels don't increase in the near future, the information from this study can be used to make management decisions regarding the current drawdown zone invasions by *B. tournefortii* and *T. ramosissima.* Additional studies on the drawdown zone of Lake Mead will provide further insights into the developmental patterns and processes of this ecosystem and the potential impacts of invasive species.

Also, because the current drawdown zone has already been invaded by *T. ramosissima* and *B. tournefortii,* it is important to continue studies on this site. *Brassica tournefortii*'s invasion of established communities and disturbed habitats combined with high seed production (Trader et al. 2006) and high seed viability (Bangle et al. in press) cause it to be of great management concern. Research has shown that *B. tournefortii* will establish in the drawdown zone as well as in the established communities. This indicates that *B. tournefortii* may establish initially in the drawdown zone where competition is minimal and then invade the established communities. Additional research is needed to determine where the initial colonization site for *B. tournefortii* is likely to be in non-invaded locales, which will enable more effective management of invasion.

APPENDIX A

TABLES AND FIGURES

Table 2-1 – Starting locations for each of the forty transects. Transects began at these locations and ran perpendicular to the shoreline and away from the water.

Tran#	Starting Locations		Description of Transect Location
	Easting	Northing	
1	694262	3999752	East of Government Wash
2	696745	3999799	500m E of Road 89
3	697877	4000089	Crawdad Cove
4	699332	3999748	Boxcar Rock
5	707883	4001631	Finger Cove
6	711120	4000092	Sandy Cove
7	735383	4033211	S. of Overton Beach
8	735752	4033770	S. of Overton Beach
9	736138	4034074	S. of Overton Beach
10	737076	4035173	S. of Overton Beach
11	737307	4035679	S. of Overton Beach
12	737361	4036062	S. of Overton Beach
13	735897	4038034	1.5 km N of Overton Beach

14	738921	4038010	Across from Black Point
15	738062	4029830	N. of Kline Hole
16	736459	4027107	S. of Glory Hole
17	735897	4025125	Lime Cove
18	735711	4023743	E of Calico Bay
19	735643	4020298	E. of Echo Bay
20	735378	4018837	Quail Bay

Tran#	Starting Locations		Description of Transect Location
	Easting	Northing	
21	735577	4015250	E of Cathedral Cove
22	735236	4013186	NE of Kendal Cove
23	734948	4012440	SE of Kendal Cove
24	734509	4009403	Catclaw Cove
25	734360	4009262	S of Twin Springs Cove
26	735108	4006927	N of Walker Bay
27	737522	4003899	Walker Bay
28	743339	3995298	Across from Temple Bar
29	743653	3994390	Across from Temple Bar
30	745516	3994035	Across from Temple Bar
31	743783	3991580	E of Temple Bar
32	741933	3991339	500 m east of Temple Bar
33	740264	3992168	1 km west of Monkey Cove
34	727498	3997201	Bonelli Landing
35	726185	3997153	0.5 km NW of Bonelli Landing
36	723529	3998761	2 km NW of Bonelli Landing
37	706660	3996032	East shore of Boulder Basin
38	705040	3994460	East shore of Boulder Basin
39	705008	3992546	Below Burro Point
40	706492	3990313	Kingman Cove

Table 2-2 – Average of soil chemistry measures by plot level with 40 plots per level.

Plot#	pH		%SOM		% sand		% clay		% silt		N Conc	
	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.
2	8.04	0.052	0.95	0.001	89.8	1.889	2.06	0.235	8.16	1.801	0.394	0.061
3	8.22	0.056	0.86	0.001	90.8	1.659	2.31	0.357	6.94	1.618	0.274	0.033
4	8.23	0.053	0.89	0.001	90.7	1.901	2.50	0.245	6.81	1.864	0.251	0.026
5	8.37	0.044	0.71	0.001	93.8	1.035	2.03	0.278	4.12	0.808	0.209	0.029
6	8.05	0.040	1.31	0.001	87.5	1.289	3.69	0.372	8.78	1.031	0.656	0.108
7	8.04	0.043	1.28	0.001	86.2	1.386	3.75	0.338	10.1	1.179	0.621	0.073

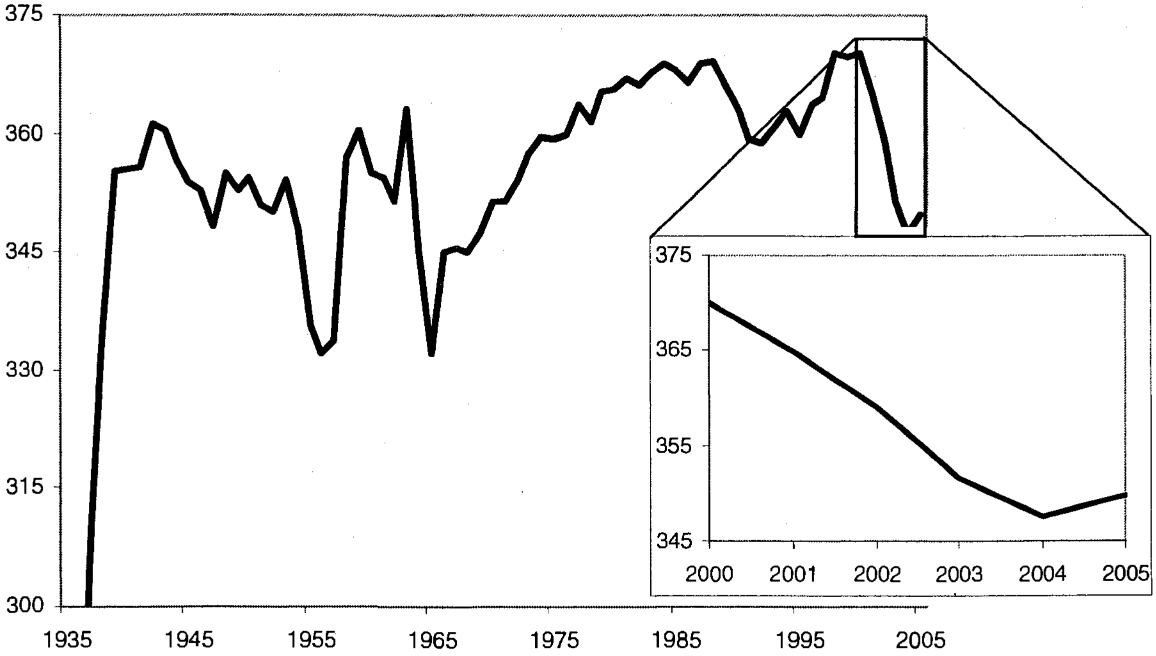

Figure 2-1. Annual water levels of Lake Mead.
http://www.usbr.gov/lc/region/lcrivops.html)

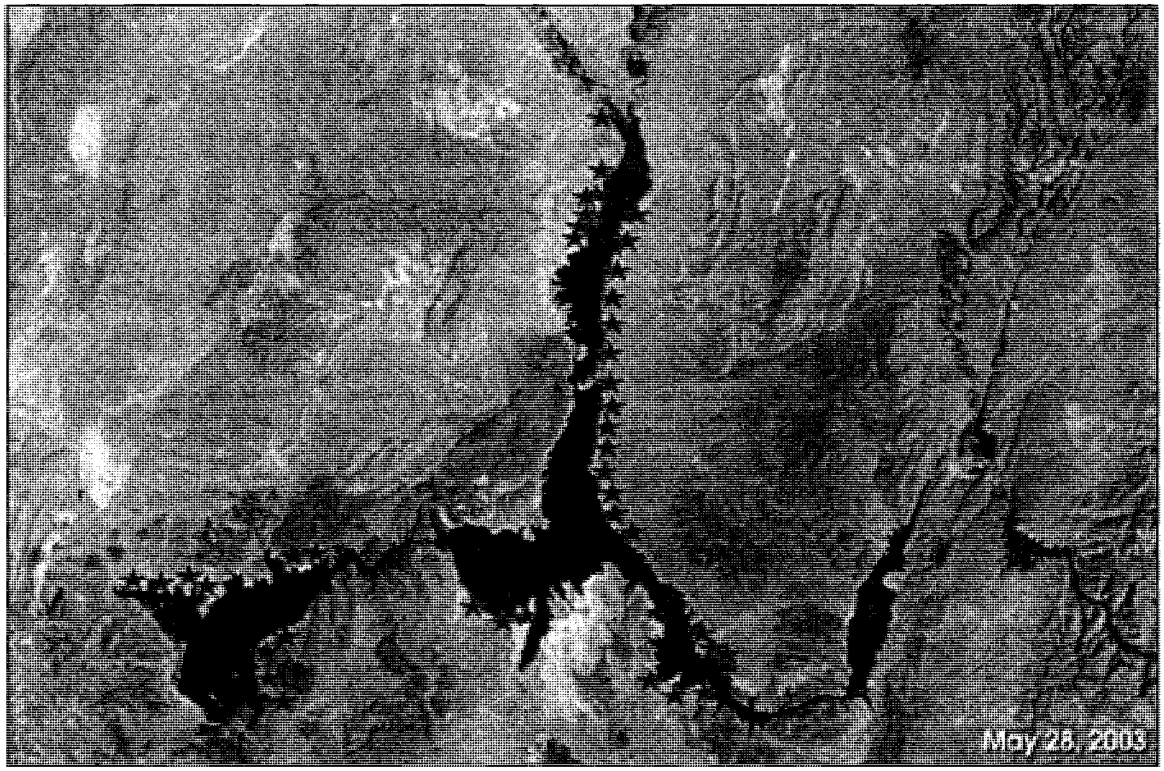

Figure 2-2. The shoreline of Lake Mead as of May 28, 2003. Stars indicate the starting location of each transect.

(http://veimages.gsfc.nasa.gov/16844/landsat_lake_mead_may04_30m.jpg)

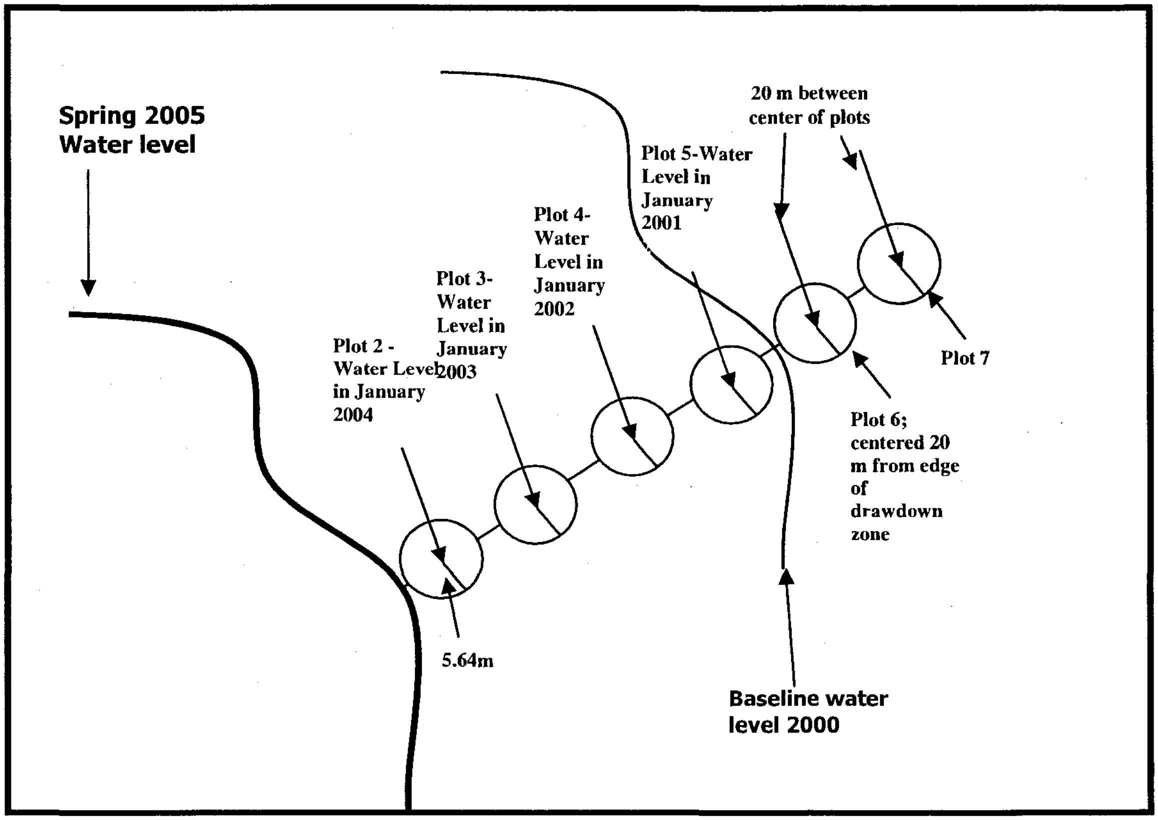

Figure 2-3. A typical transect. Plots 2-5 were located in the drawdown zone at elevations reflecting water levels in January 2001-2004. Plot #1 was removed from the analysis as it was covered by water in the middle of surveying). Plots 6 and 7 were higher than the 2000 shoreline and were separated by 20 m (horizontal distance along the soil surface).

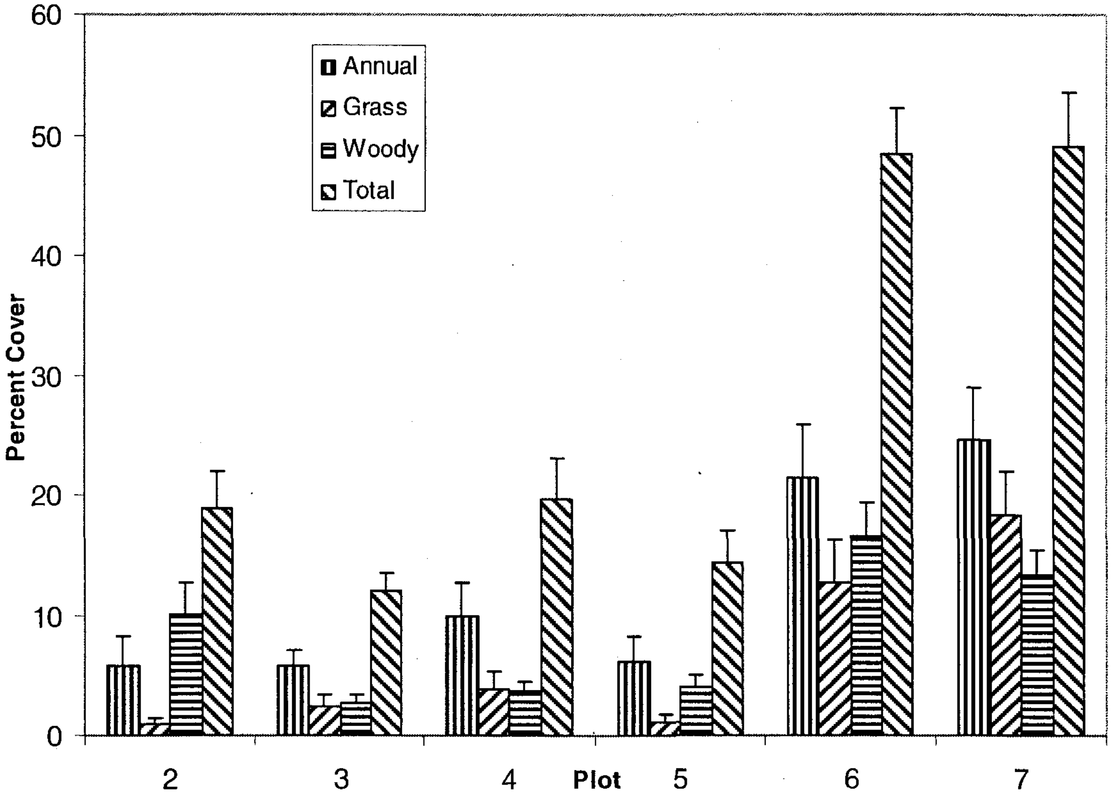

Figure 2-4. Mean cover by plant group across all plots using the midpoint of each cover class; bars indicate SE. Bryophytes and suffrutescents were not included due to their minimal cover.

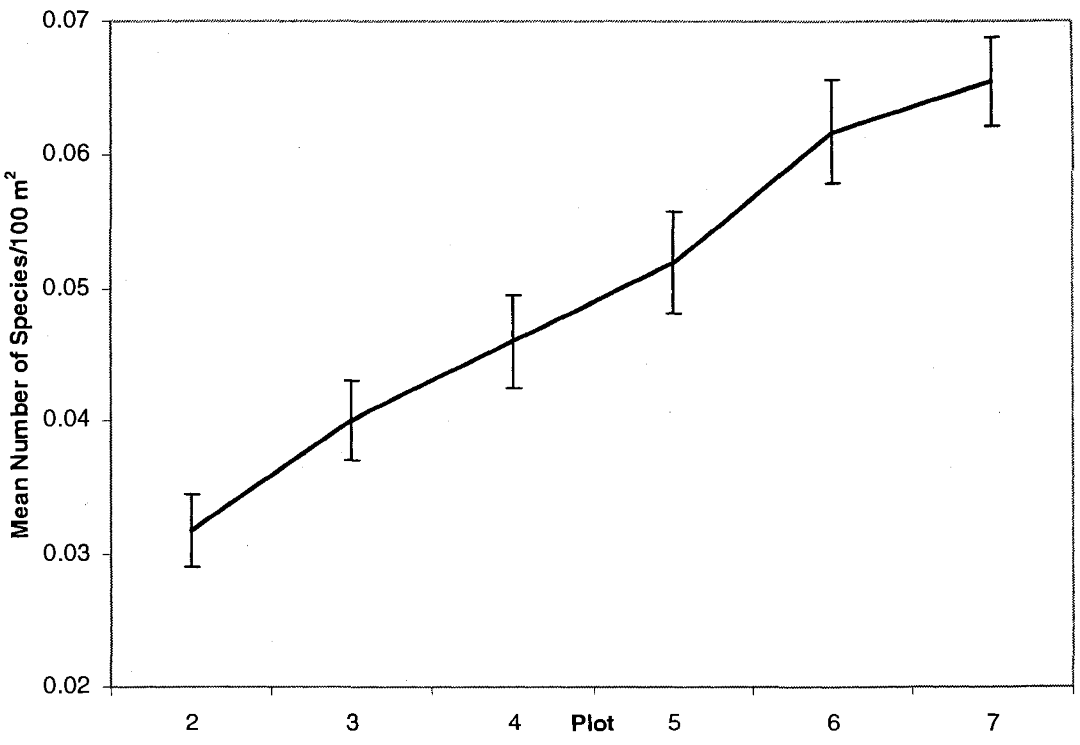

Figure 2-5. Mean number of species averaged across all 40 plots per plot level. Bars indicate standard error.

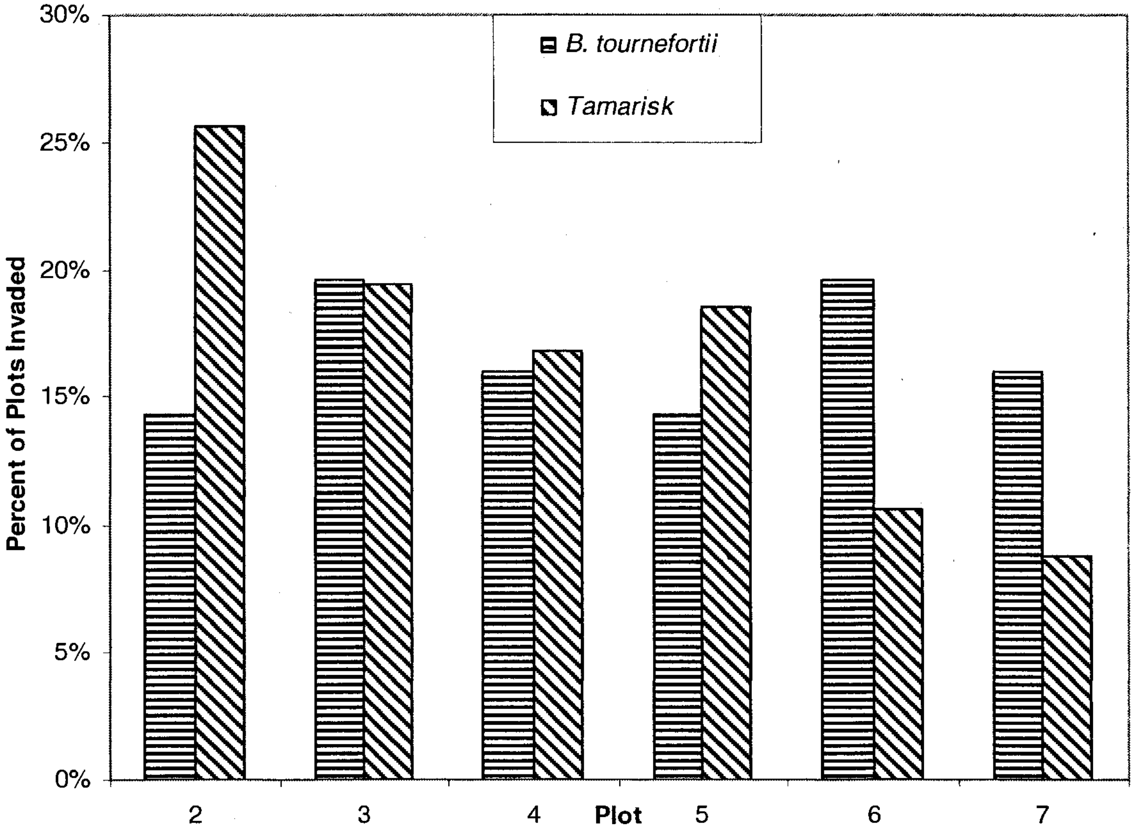

Figure 2-6. Distribution of plots with either *Brassica tournefortii* or *Tamarix ramosissima*. *Brassica tournefortii* was present in 56 plots and *T. ramosissima* was present in 113 of 240 plots.

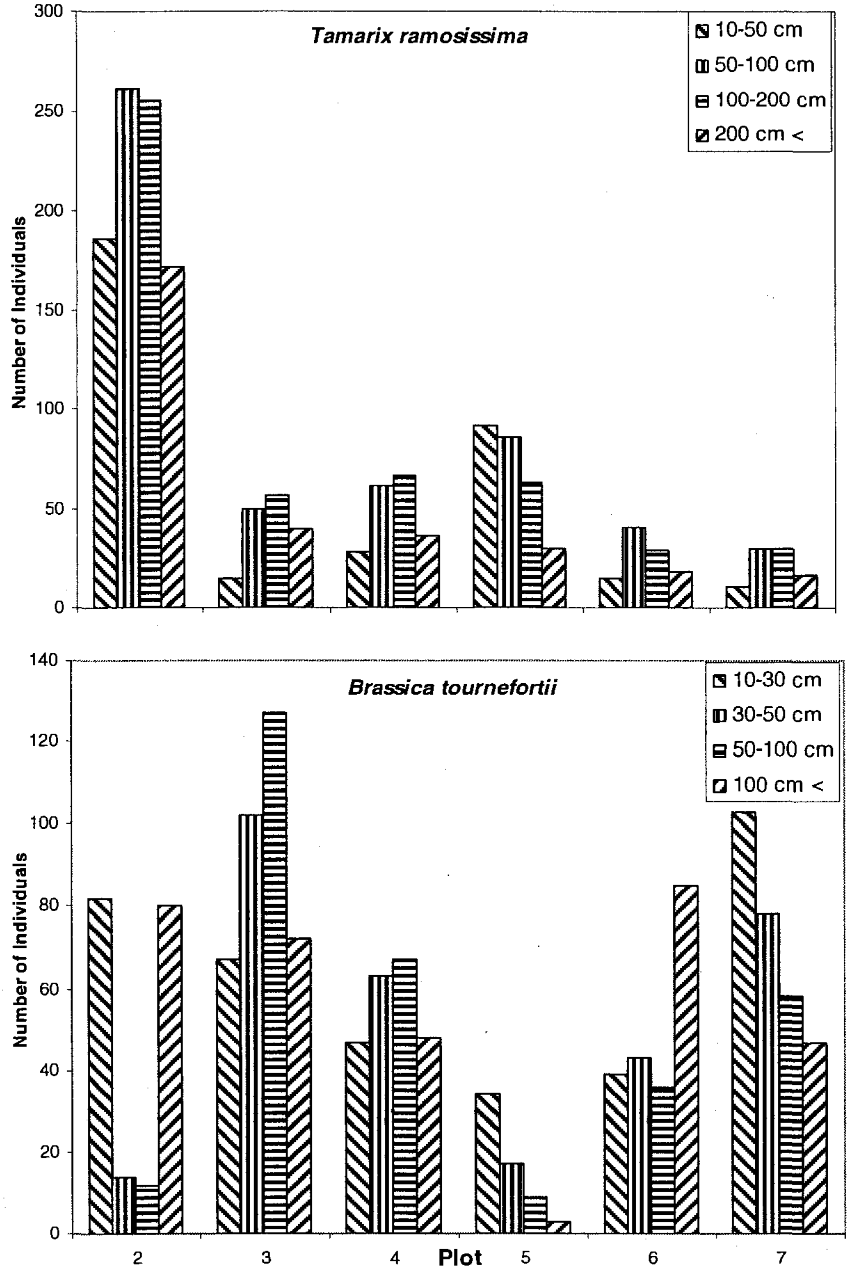

Figure 2-7 – Variation in size and number of *Tamarix ramosissima* and *Brassica tournefortii* across all plots.

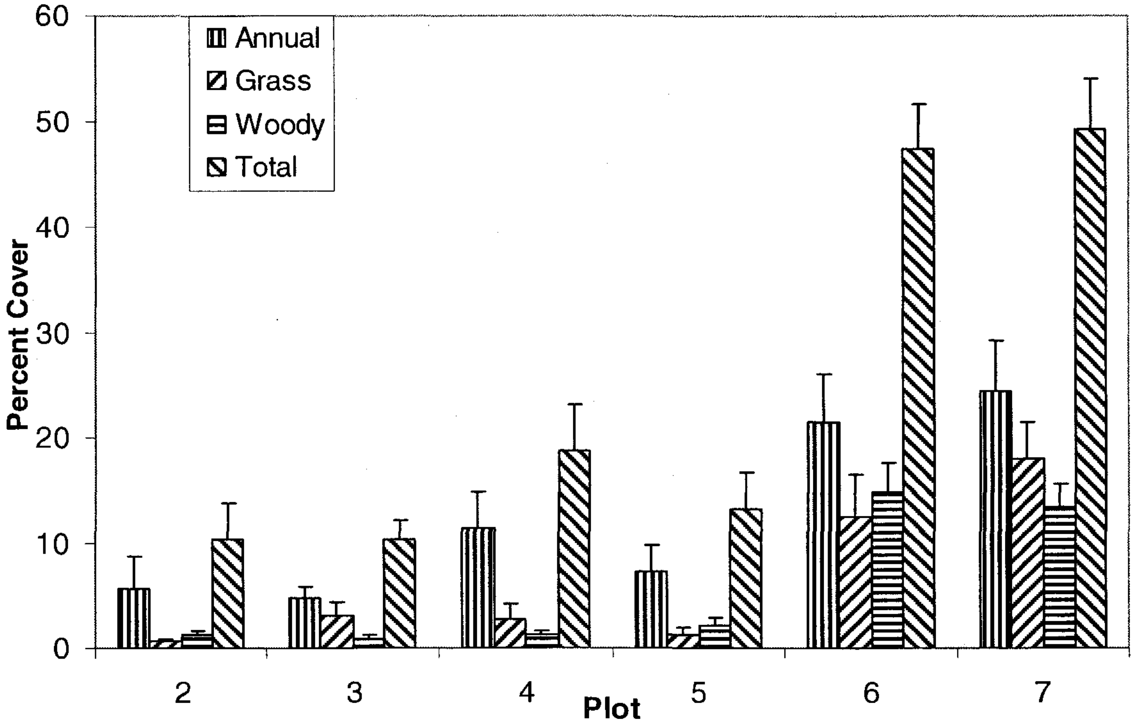

Figure 2-8. Mean cover of plant groups across all plots after the removal of plots dominated by the invasive species *T. ramosissima* and *B. tournefortii*. Means calculated using midpoint of cover classes and bars indicate SE.

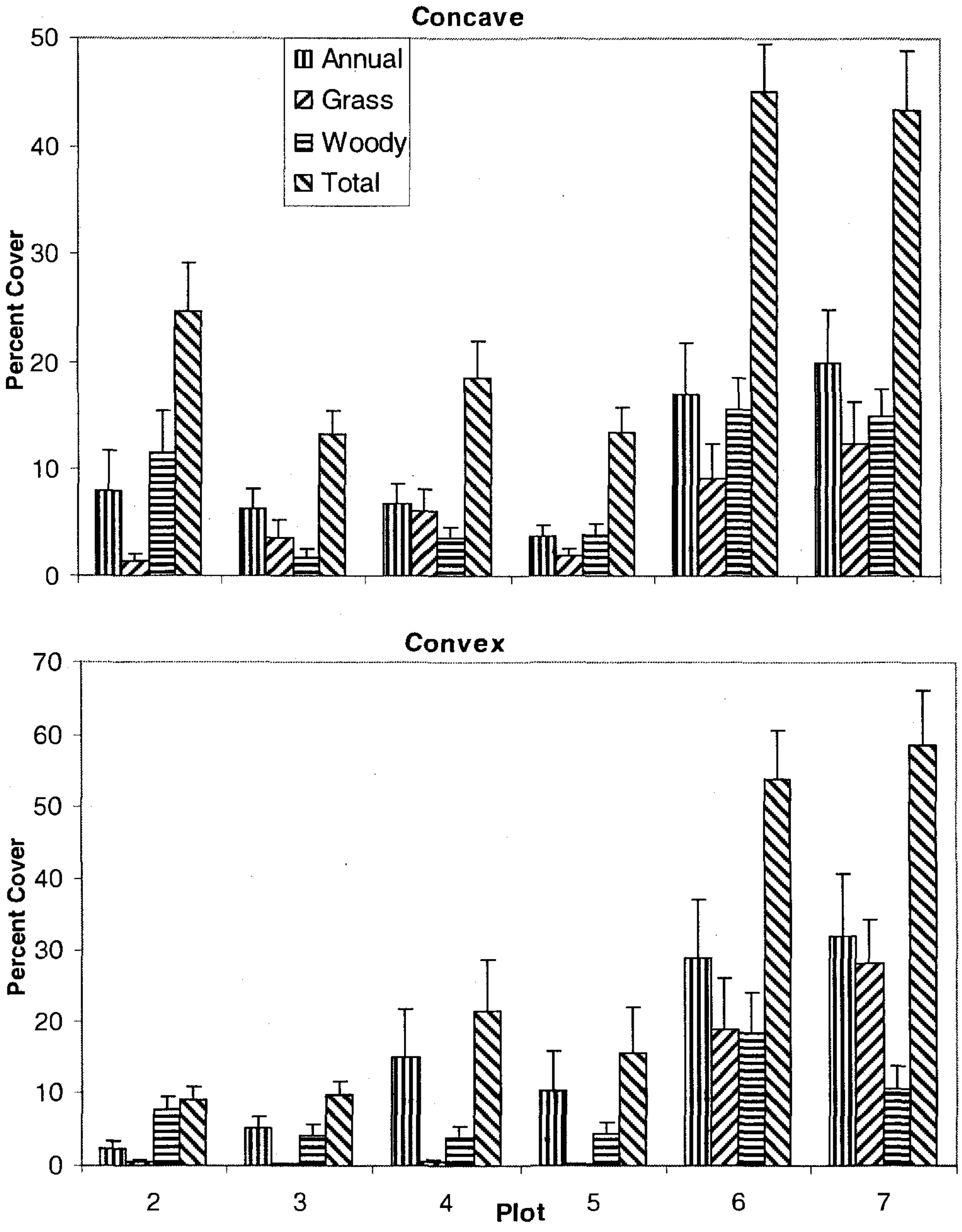

Figure 2-9. Average cover by plant groups on concave versus convex shorelines. Means calculated using midpoints of cover classes and bars indicate SE.

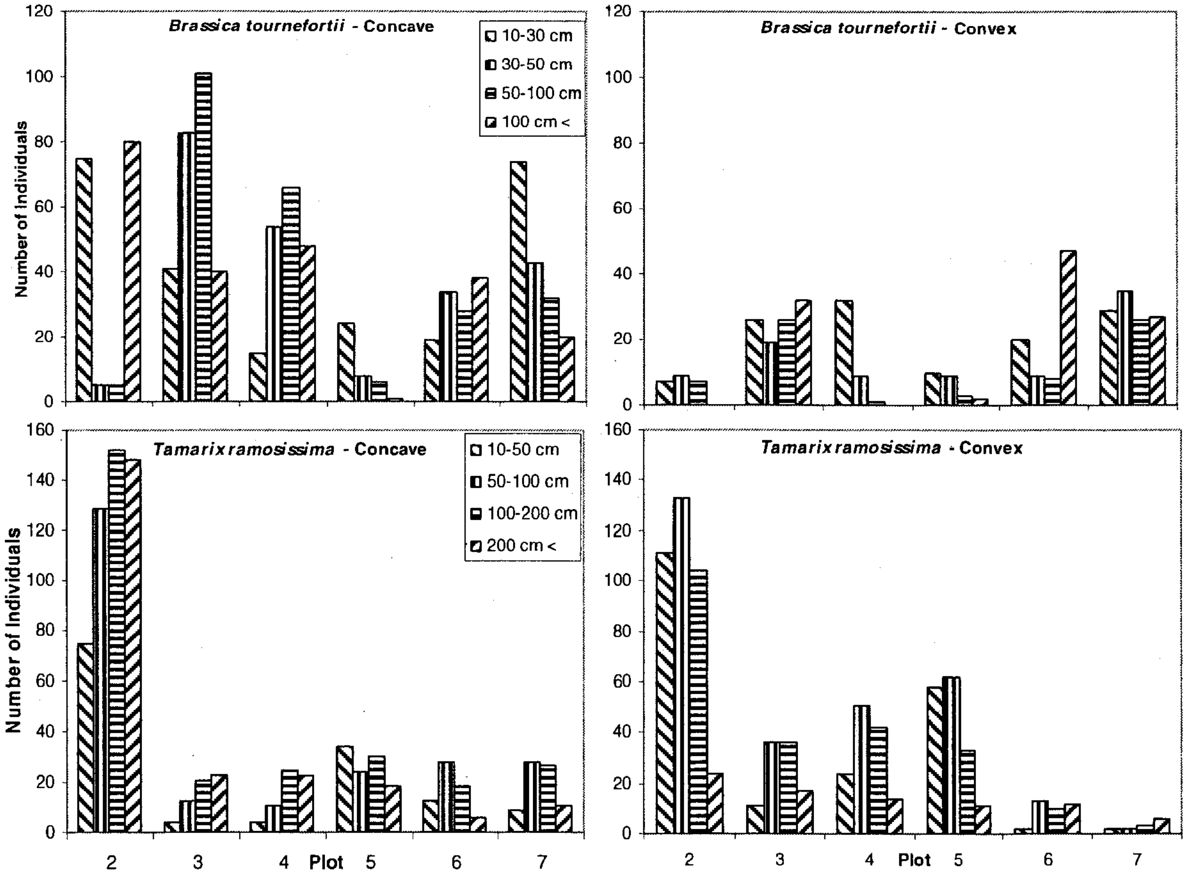

Figure 2-10. Comparison of invasion of *B. tournefortii* and *T. ramosissima* on concave versus convex shorelines. Bars indicate the number of individuals within each height based category.

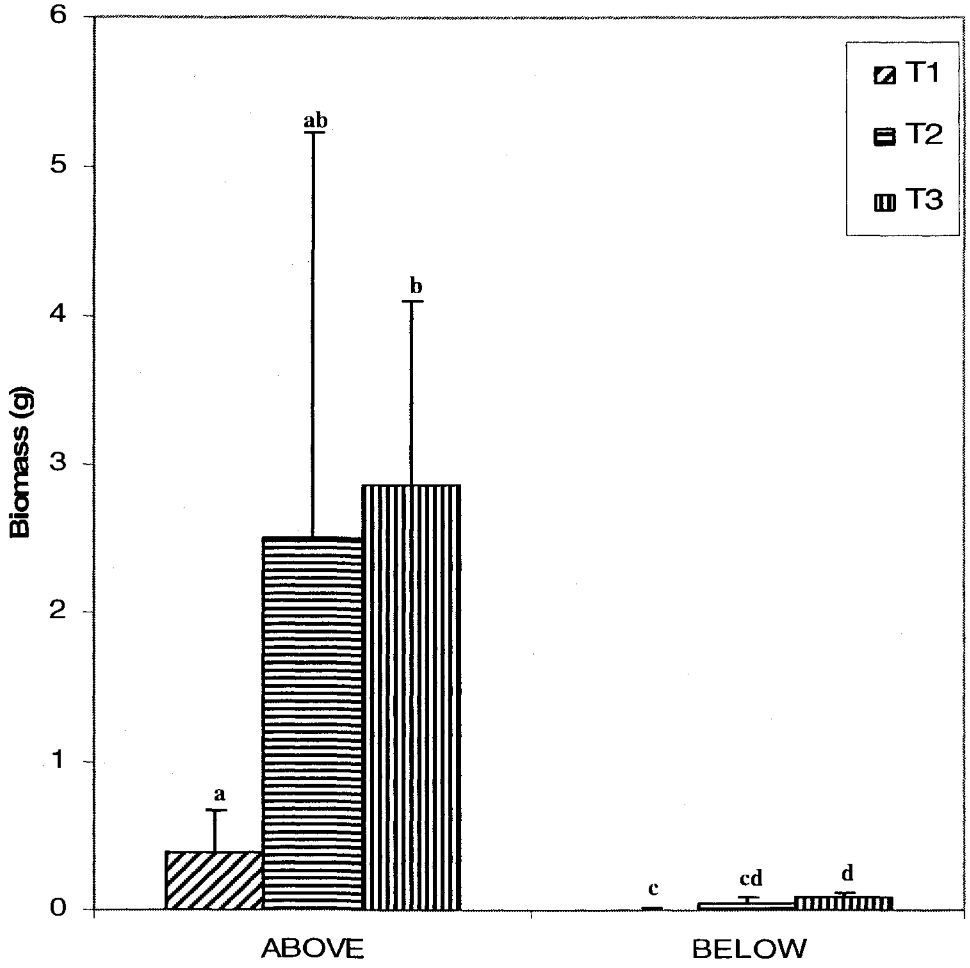

Figure 3-1. Mean above and belowground biomass across all three treatments for *Camissonia claviformis*. In treatment *B. tournefortii* was germinated and sown four weeks prior to the native species; treatment 2 both species were germinated and sown at the same time; and, in treatment 3, the native species was germinated and sown four weeks prior to *B. tournefortii*. Bars indicate standard errors and different letters indicate statistically significant differences.

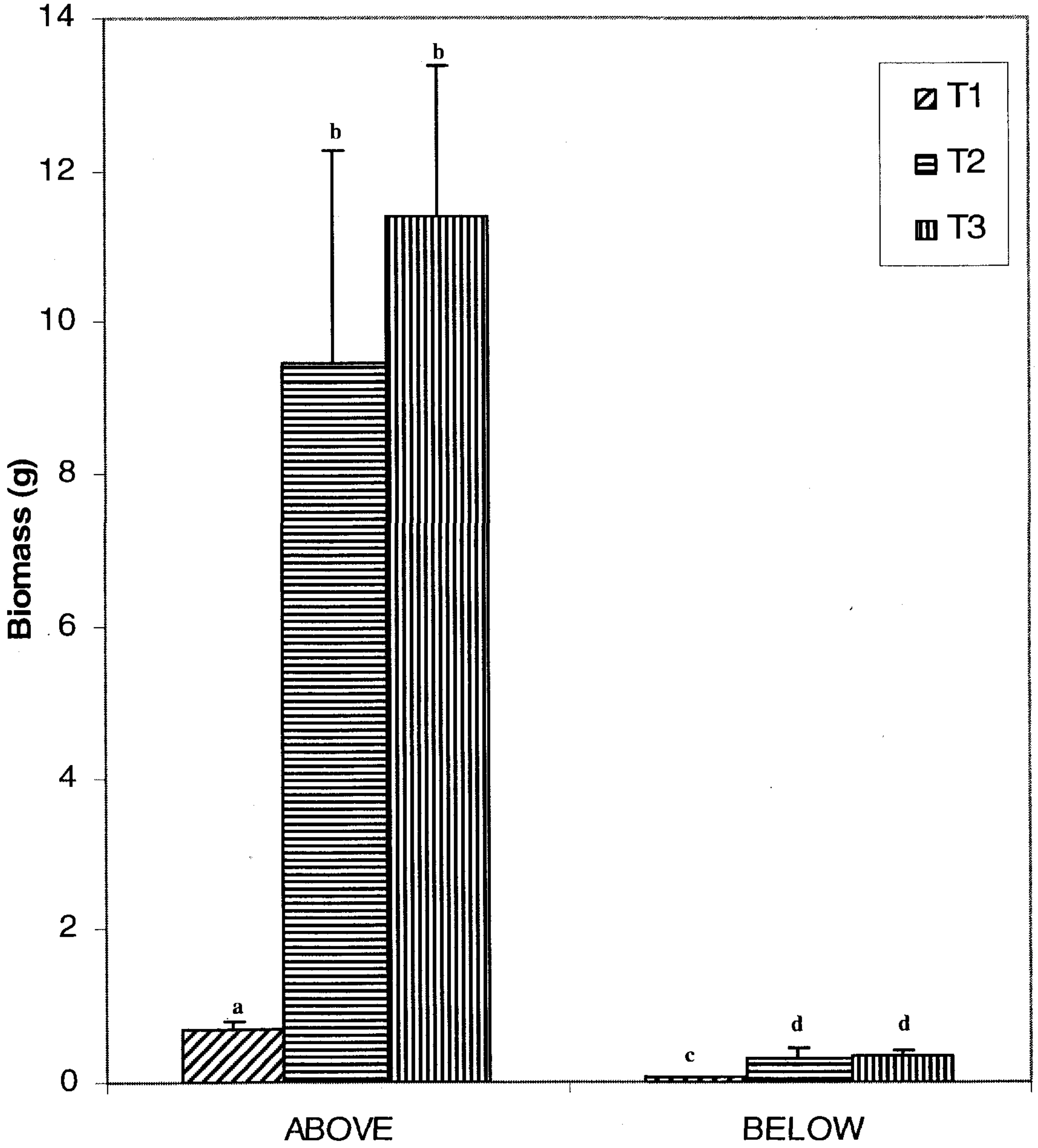

Figure 3-2 – Mean above and belowground biomass across all three treatments for *Geraea canescens*. Bars indicate standard errors and different letters indicate statistically significant differences. See Figure 3-1 for treatment description.

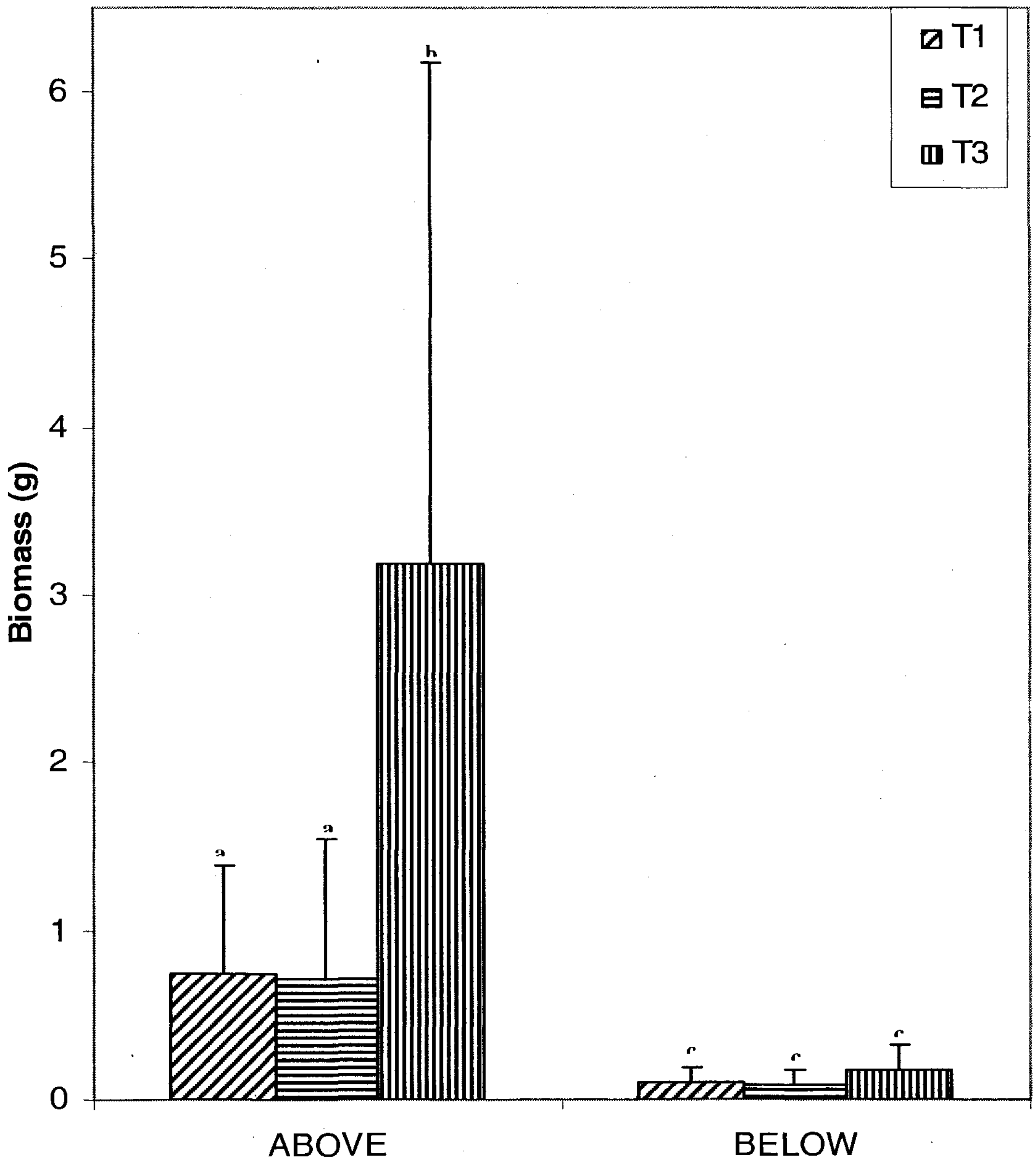

Figure 3-3. Mean above and belowground biomass across all three treatments for *Lupinus arizonicus*. Bars indicate standard errors and different letters indicate statistically significant differences. See Figure 3-1 for treatment description.

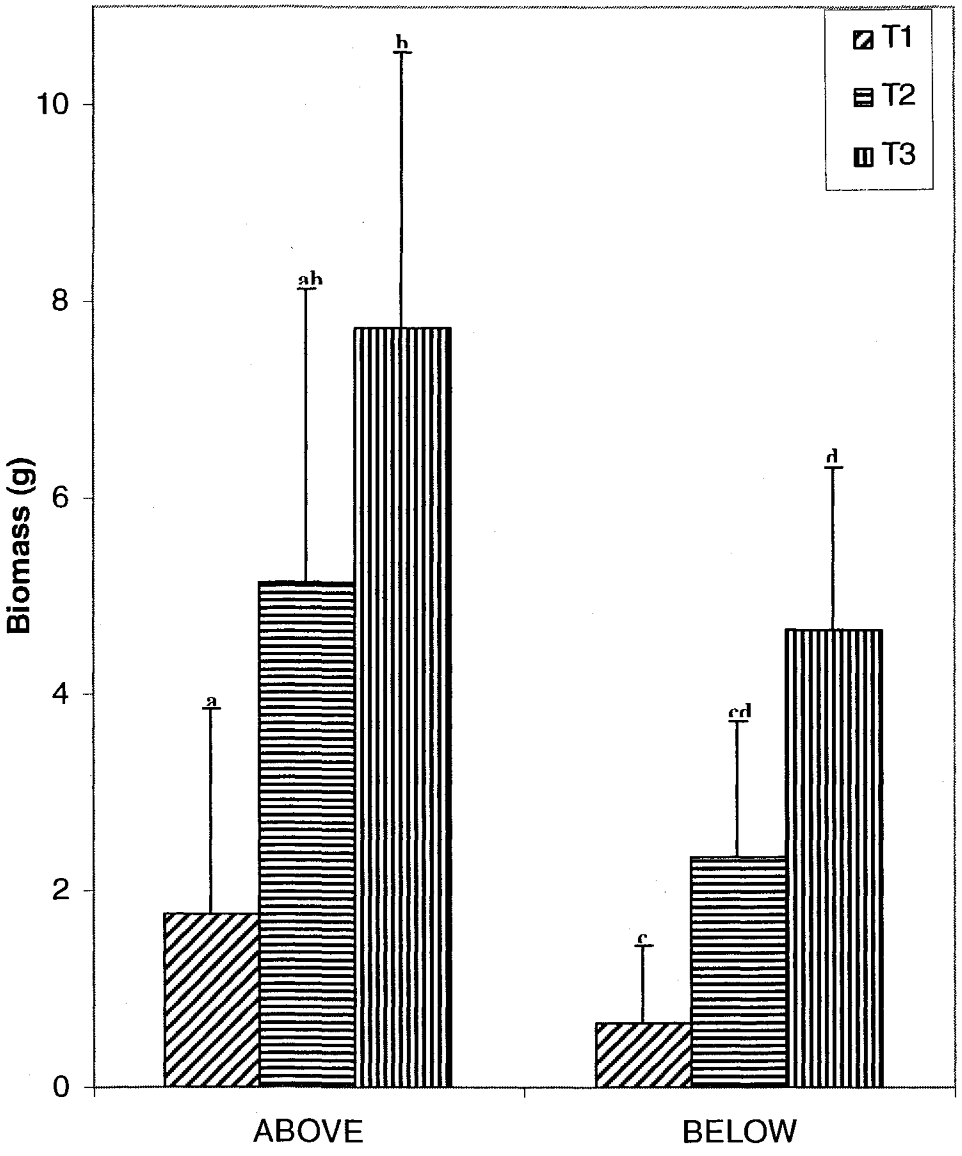

Figure 3-4. Mean above and belowground biomass across all three treatments for *Sphaeralcea ambigua*. Bars indicate standard errors and different letters indicate statistically significant differences. See Figure 3-1 for treatment description.

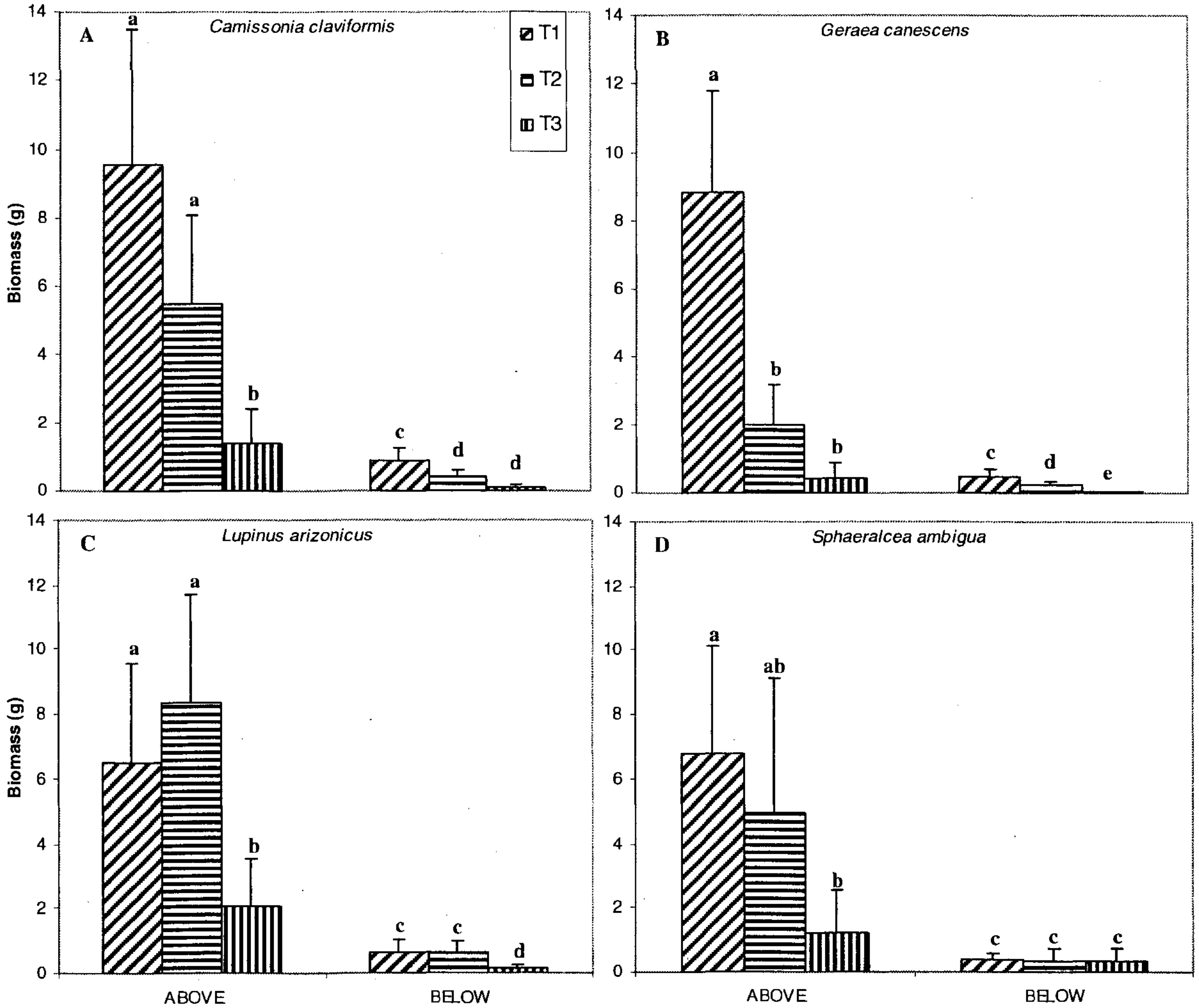

Figure 3-5. Mean above and belowground biomass across all three treatments for *Brassica tournefortii* grown in concert with four native species. Bars indicate standard errors and different letters indicate statistically significant differences. See Figure 3-1 for treatment description.

APPENDIX B

LOCATION OF TRANSECTS

Description of the center point of each plot using GPS coordinates as well as a generalized description.

Tran#	Plot#	Center of Plot		Description of Transect Location
		Easting	Northing	
1	2	694262	3999752	East of Government Wash
1	3	694291	3999766	East of Government Wash
1	4	694311	3999776	East of Government Wash
1	5	694342	3999788	East of Government Wash
1	6	694442	4000031	East of Government Wash
1	7	694442	4000050	East of Government Wash
2	2	696745	3999799	500m E of Road 89
2	3	696781	3999904	500m E of Road 89
2	4	696799	3999955	500m E of Road 89
2	5	696822	4000004	500m E of Road 89
2	6	696928	4000271	500m E of Road 89
2	7	696945	4000277	500m E of Road 89
3	2	697877	4000089	Crawdad Cove
3	3	697826	4000139	Crawdad Cove
3	4	697801	4000172	Crawdad Cove
3	5	697777	4000204	Crawdad Cove
3	6	697761	4000220	Crawdad Cove
3	7	697751	4000228	Crawdad Cove
4	2	699332	3999748	Boxcar Rock
4	3	699326	3999862	Boxcar Rock
4	4	699331	4000033	Boxcar Rock
4	5	699312	4000150	Boxcar Rock
4	6	699310	4000177	Boxcar Rock
4	7	699310	4000198	Boxcar Rock
5	2	707883	4001631	Finger Cove
5	3	707906	4001632	Finger Cove
5	4	707926	4001683	Finger Cove
5	5	707931	4001649	Finger Cove

5	6	707945	4001660	Finger Cove
5	7	707955	4001672	Finger Cove
6	2	711120	4000092	Sandy Cove
6	3	710397	4001920	Sandy Cove
6	4	710416	4001990	Sandy Cove
6	5	710430	4002044	Sandy Cove
6	6	710432	4002064	Sandy Cove
6	7	710432	4002076	Sandy Cove
7	2	735383	4033211	S. of Overton Beach
7	3	735354	4033204	S. of Overton Beach
7	4	735340	4033203	S. of Overton Beach
7	5	735324	4033204	S. of Overton Beach
7	6	735309	4033200	S. of Overton Beach
7	7	735302	4033188	S. of Overton Beach
8	2	735752	4033770	S. of Overton Beach
8	3	735720	4033857	S. of Overton Beach
8	4	735715	4033907	S. of Overton Beach
8	5	735701	4033930	S. of Overton Beach
8	6	735693	4033934	S. of Overton Beach
8	7	735691	4033944	S. of Overton Beach
9	2	736138	4034074	S. of Overton Beach
9	3	736130	4034127	S. of Overton Beach
9	4	736127	4034178	S. of Overton Beach
9	5	736116	4034192	S. of Overton Beach
9	6	736104	4034217	S. of Overton Beach
9	7	736089	4034221	S. of Overton Beach
10	2	737076	4035173	S. of Overton Beach
10	3	737026	4035217	S. of Overton Beach
10	4	737000	4035240	S. of Overton Beach
10	5	736973	4035267	S. of Overton Beach
10	6	736968	4035268	S. of Overton Beach
10	7	736955	4035281	S. of Overton Beach
11	2	737307	4035679	S. of Overton Beach
11	3	737255	4035668	S. of Overton Beach
11	4	737219	4035654	S. of Overton Beach
11	5	737195	4035644	S. of Overton Beach
11	6	737164	4035637	S. of Overton Beach
11	7	737151	4035629	S. of Overton Beach
12	2	737361	4036062	S. of Overton Beach
12	3	737313	4036057	S. of Overton Beach
12	4	737261	4036025	S. of Overton Beach
12	5	737231	4036000	S. of Overton Beach
12	6	737220	4035984	S. of Overton Beach
12	7	737203	4035989	S. of Overton Beach

13	2	735897	4038034	1.5 km N of Overton Beach
13	3	735870	4037981	1.5 km N of Overton Beach
13	4	735863	4037960	1.5 km N of Overton Beach
13	5	735851	4037936	1.5 km N of Overton Beach
13	6	735837	4037921	1.5 km N of Overton Beach
13	7	735820	4037907	1.5 km N of Overton Beach
14	2	738921	4038010	Across from Black Point
14	3	738934	4037991	Across from Black Point
14	4	738937	4037970	Across from Black Point
14	5	738946	4037959	Across from Black Point
14	6	738947	4037939	Across from Black Point
14	7	738951	4037932	Across from Black Point
15	2	738062	4029830	N. of Kline Hole
15	3	738091	4029829	N. of Kline Hole
15	4	738108	4029832	N. of Kline Hole
15	5	738137	4029826	N. of Kline Hole
15	6	738158	4029820	N. of Kline Hole
15	7	738183	4029805	N. of Kline Hole
16	2	736459	4027107	S. of Glory Hole
16	3	736496	4027144	S. of Glory Hole
16	4	736533	4027138	S. of Glory Hole
16	5	736556	4027155	S. of Glory Hole
16	6	736573	4027164	S. of Glory Hole
16	7	736592	4027166	S. of Glory Hole
17	2	735897	4025125	Lime Cove
17	3	735929	4025125	Lime Cove
17	4	735961	4025128	Lime Cove
17	5	735998	4025128	Lime Cove
17	6	735014	4025136	Lime Cove
17	7	736031	4025149	Lime Cove
18	2	735711	4023743	E of Calico Bay
18	3	735713	4023755	E of Calico Bay
18	4	735708	4023763	E of Calico Bay
18	5	735705	4023785	E of Calico Bay
18	6	735699	4023824	E of Calico Bay
18	7	735700	4023826	E of Calico Bay
19	2	735643	4020298	E. of Echo Bay
19	3	735676	4020285	E. of Echo Bay
19	4	735716	4020273	E. of Echo Bay
19	5	735744	4020269	E. of Echo Bay
19	6	735767	4020267	E. of Echo Bay
19	7	735790	4020259	E. of Echo Bay
20	2	735378	4018837	Quail Bay
20	3	735408	4018862	Quail Bay

20	4	735441	4018881	Quail Bay
20	5	735472	4018897	Quail Bay
20	6	735491	4018909	Quail Bay
20	7	735512	4018913	Quail Bay
21	2	735577	4015250	E of Cathedral Cove
21	3	735634	4015296	E of Cathedral Cove
21	4	735664	4015322	E of Cathedral Cove
21	5	735701	4015348	E of Cathedral Cove
21	6	735714	4015363	E of Cathedral Cove
21	7	735735	4015358	E of Cathedral Cove
22	2	735236	4013186	NE of Kendal Cove
22	3	735334	4013217	NE of Kendal Cove
22	4	735417	4013221	NE of Kendal Cove
22	5	735481	4013242	NE of Kendal Cove
22	6	735495	4013241	NE of Kendal Cove
22	7	735527	4013246	NE of Kendal Cove
23	2	734948	4012440	SE of Kendal Cove
23	3	735031	4012432	SE of Kendal Cove
23	4	735102	4012425	SE of Kendal Cove
23	5	735194	4012415	SE of Kendal Cove
23	6	735216	4012411	SE of Kendal Cove
23	7	735229	4012411	SE of Kendal Cove
24	2	734509	4009403	Catclaw Cove
24	3	734953	4010678	Catclaw Cove
24	4	735004	4010630	Catclaw Cove
24	5	735091	4010580	Catclaw Cove
24	6	735109	4010571	Catclaw Cove
24	7	735114	4010556	Catclaw Cove
25	2	734360	4009262	S of Twin Springs Cove
25	3	734406	4009304	S of Twin Springs Cove
25	4	734448	4009346	S of Twin Springs Cove
25	5	734469	4009364	S of Twin Springs Cove
25	6	734496	4009393	S of Twin Springs Cove
25	7	734511	4009403	S of Twin Springs Cove
26	2	735108	4006927	N of Walker Bay
26	3	735226	4006991	N of Walker Bay
26	4	735281	4007061	N of Walker Bay
26	5	735333	4007128	N of Walker Bay
26	6	735344	4007144	N of Walker Bay
26	7	735393	4007153	N of Walker Bay
27	2	737522	4003899	Walker Bay
27	3	737567	4003917	Walker Bay
27	4	737610	4003938	Walker Bay
27	5	737635	4003942	Walker Bay

27	6	737657	4003951	Walker Bay
27	7	737666	4003962	Walker Bay
28	2	743339	3995298	Across from Temple Bar
28	3	743376	3995315	Across from Temple Bar
28	4	743423	3995328	Across from Temple Bar
28	5	743470	3995342	Across from Temple Bar
28	6	743476	3995346	Across from Temple Bar
28	7	743505	3995352	Across from Temple Bar
29	2	743653	3994390	Across from Temple Bar
29	3	743672	3994436	Across from Temple Bar
29	4	743707	3994490	Across from Temple Bar
29	5	743746	3994536	Across from Temple Bar
29	6	743758	3994560	Across from Temple Bar
29	7	743775	3994580	Across from Temple Bar
30	2	745516	3994035	Across from Temple Bar
30	3	745532	3994065	Across from Temple Bar
30	4	745561	3994100	Across from Temple Bar
30	5	745578	3994127	Across from Temple Bar
30	6	745587	3994143	Across from Temple Bar
30	7	745591	3994156	Across from Temple Bar
31	2	743783	3991580	E of Temple Bar
31	3	743764	3991571	E of Temple Bar
31	4	743751	3991545	E of Temple Bar
31	5	743740	3991546	E of Temple Bar
31	6	743716	3991537	E of Temple Bar
31	7	743716	3991523	E of Temple Bar
32	2	741933	3991339	500 m east of Temple Bar
32	3	741911	3991311	500 m east of Temple Bar
32	4	741904	3991290	500 m east of Temple Bar
32	5	741895	3991257	500 m east of Temple Bar
32	6	741893	3991233	500 m east of Temple Bar
32	7	741897	3991228	500 m east of Temple Bar
33	2	740264	3992168	1 km west of Monkey Cove
33	3	740216	3992221	1 km west of Monkey Cove
33	4	740190	3992233	1 km west of Monkey Cove
33	5	740178	3992248	1 km west of Monkey Cove
33	6	740165	3992259	1 km west of Monkey Cove
33	7	740147	3992269	1 km west of Monkey Cove
34	2	727498	3997201	Bonelli Landing
34	3	727431	3997105	Bonelli Landing
34	4	727412	3997050	Bonelli Landing
34	5	727387	3996955	Bonelli Landing
34	6	727386	3996764	Bonelli Landing
34	7	727388	3996755	Bonelli Landing

35	2	726185	3997153	0.5 km NW of Bonelli Landing
35	3	726147	3997078	0.5 km NW of Bonelli Landing
35	4	726102	3997005	0.5 km NW of Bonelli Landing
35	5	726049	3996900	0.5 km NW of Bonelli Landing
35	6	725986	3996800	0.5 km NW of Bonelli Landing
35	7	725974	3996783	0.5 km NW of Bonelli Landing
36	2	723529	3998761	2 km NW of Bonelli Landing
36	3	723466	3998750	2 km NW of Bonelli Landing
36	4	723423	3998740	2 km NW of Bonelli Landing
36	5	723385	3998730	2 km NW of Bonelli Landing
36	6	723367	3998721	2 km NW of Bonelli Landing
36	7	723353	3998709	2 km NW of Bonelli Landing
37	2	706660	3996032	East shore of Boulder Basin
37	3	706674	3995975	East shore of Boulder Basin
37	4	706692	3995939	East shore of Boulder Basin
37	5	706710	3995901	East shore of Boulder Basin
37	6	706722	3995883	East shore of Boulder Basin
37	7	706729	3995864	East shore of Boulder Basin
38	2	705040	3994460	East shore of Boulder Basin
38	3	705071	3994455	East shore of Boulder Basin
38	4	705106	4994453	East shore of Boulder Basin
38	5	705112	3994455	East shore of Boulder Basin
38	6	705133	3994451	East shore of Boulder Basin
38	7	705153	3994448	East shore of Boulder Basin
39	2	705008	3992546	Below Burro Point
39	3	705031	3992552	Below Burro Point
39	4	705057	3992555	Below Burro Point
39	5	705091	3992564	Below Burro Point
39	6	705134	3992609	Below Burro Point
39	7	705151	3992614	Below Burro Point
40	2	706492	3990313	Kingman Cove
40	3	706487	3990289	Kingman Cove
40	4	706480	3990273	Kingman Cove
40	5	706480	3990252	Kingman Cove
40	6	706478	3990244	Kingman Cove
40	7	706482	3990224	Kingman Cove

APPENDIX C

TRANSECT DATA COLLECTION SHEET

Example of data sheets used to collect data during field surveys.

Lake Mead Transect Data Sheets

Name:________________________ Date: ____________ Dir.: ____ Aspect: ____

Tran.# __ Plot# __ Distance from Last Plot (m) ___

Easting ____________ Northing __________ Elev: _____ Slope: ________

Transect Location Est.: ____

Shoreline: Convex or Concave Total % Cover: ____________________ Grass % Cover: _______

Bryo. % Cover: _____ "Woody" % Cover: Suff. % Cover: _______ Annual % Cover: ____

Species	Hgt (m)	D 1 (m)	D 2 (m)	% Cover - sp	Comments
Comments:					

Cover Classes	Rocks	Litter Removal (cm):	*B. tournefortii*	*E. deflexum*	*T. ramossissima*
+: <1%		0	B1: 10-30	E1: 10-30	T1: 10-50
1: 1% - 5%	% Gravel (.2-2 cm) _____	1			
2: 6% - 25%		2	B2: 30-50	E2: 30-50	T2: 50-100
3: 26 - 50%	% Cobble (2-10 cm) ____	3			
4: 51 - 75%		4	B3: 50 - 100	E3: 50 - 100	T3:100-200
5: 76 - 95%	% Boulder (10+ cm) ___				
6: 96 - 100%			B4: 100+	E4: 100+	T4: 200+

APPENDIX D

PLANT GROUPD COVER DATA

Cover class data by plant group collected during field surveys.

Tran#	Plot#	Sufr. Cover	Grass Cover	Bryophyte Cover	Woody Cover	Annual Cover	Total Cover
1	2	+	1	0	1	0	2
1	3	+	+	0	0	2	2
1	4	0	2	0	2	1	3
1	5	0	0	0	2	+	2
1	6	0	+	0	2	1	3
1	7	1	1	0	2	2	3
2	2	0	+	0	1	+	1
2	3	+	+	0	0	+	+
2	4	0	+	0	1	1	2
2	5	0	0	0	0	1	1
2	6	+	3	0	3	2	4
2	7	0	4	0	1	4	5
3	2	0	+	1	5	0	5
3	3	0	+	0	0	1	1
3	4	0	0	0	0	1	1
3	5	+	+	0	0	1	1
3	6	+	+	0	3	2	3
3	7	0	+	0	2	1	2
4	2	0	0	0	1	1	1
4	3	0	+	0	1	1	2
4	4	0	1	0	1	1	2
4	5	+	0	0	0	1	1
4	6	0	3	0	2	1	4
4	7	0	3	0	2	3	5
5	2	0	+	0	2	1	2
5	3	0	0	0	1	2	2
5	4	0	0	0	1	5	5
5	5	0	0	0	1	4	4
5	6	0	0	0	2	5	5
5	7	0	2	0	1	5	5
6	2	2	1	0	0	1	2
6	3	1	1	0	+	1	1
6	4	+	3	0	0	2	3
6	5	0	2	0	0	2	2
6	6	0	1	0	3	1	3

6	7	0	2	0	3	1	3
7	2	1	0	0	3	0	3
7	3	+	0	0	2	0	2
7	4	0	0	0	1	0	1
7	5	0	0	0	2	0	2
7	6	0	0	0	2	+	2
7	7	+	+	0	1	+	1
8	2	2	+	0	2	+	3
8	3	+	+	0	1	0	1
8	4	0	0	0	1	+	1
8	5	0	+	0	1	1	2
8	6	0	1	0	1	2	3
8	7	0	+	0	1	3	3
9	2	+	0	0	1	0	1
9	3	+	1	0	1	1	2
9	4	0	+	0	0	1	1
9	5	0	+	0	1	+	1
9	6	0	1	0	1	2	3
9	7	0	+	0	1	1	2
10	2	+	+	0	0	+	+
10	3	+	0	0	2	1	2
10	4	0	0	0	0	+	+
10	5	+	0	0	1	+	1
10	6	0	1	0	2	2	3
10	7	0	+	0	2	1	2
11	2	+	+	0	0	+	+
11	3	0	+	0	0	1	1
11	4	0	+	0	2	+	2
11	5	+	+	0	2	+	2
11	6	+	1	0	2	1	3
11	7	+	2	0	2	1	3
12	2	+	+	0	1	0	1
12	3	+	1	0	0	0	1
12	4	0	2	0	2	+	3
12	5	+	+	0	2	+	2
12	6	+	0	0	1	+	1
12	7	1	+	0	1	+	2
13	2	0	+	3	1	0	3
13	3	0	+	0	2	0	2
13	4	+	1	0	0	+	1
13	5	0	+	0	1	0	1
13	6	0	3	0	2	0	3
13	7	0	1	1	1	+	2
14	2	0	+	0	0	+	+
14	3	0	+	0	+	+	1
14	4	0	+	0	1	1	2
14	5	0	1	0	0	+	1
14	6	0	1	0	2	1	3
14	7	0	1	0	1	2	2

15	2	0	+	0	3	+	3
15	3	0	1	0	0	2	2
15	4	0	+	0	0	1	1
15	5	0	+	0	0	+	+
15	6	0	0	0	2	0	2
15	7	0	1	0	2	0	2
16	2	0	0	0	0	4	4
16	3	0	+	0	0	2	2
16	4	0	+	0	0	2	2
16	5	0	+	0	0	1	1
16	6	0	1	0	1	2	2
16	7	0	1	0	2	3	4
17	2	0	+	0	2	2	3
17	3	0	+	0	+	1	2
17	4	+	0	0	0	1	1
17	5	+	0	0	0	1	1
17	6	+	+	0	2	2	3
17	7	0	+	0	1	2	2
18	2	0	+	0	2	+	2
18	3	0	+	0	+	1	1
18	4	0	0	0	0	2	2
18	5	0	0	0	0	+	+
18	6	+	+	0	2	2	3
18	7	+	+	0	2	3	3
19	2	0	+	0	1	1	2
19	3	0	0	0	0	1	1
19	4	0	0	0	2	+	2
19	5	0	+	0	1	1	2
19	6	+	4	0	1	1	5
19	7	0	5	0	2	1	5
20	2	0	0	0	+	1	1
20	3	0	+	0	1	1	1
20	4	0	+	0	0	1	1
20	5	+	0	0	1	1	1
20	6	+	2	0	1	3	3
20	7	+	3	0	2	1	3
21	2	0	+	0	1	+	1
21	3	0	0	0	1	0	1
21	4	0	0	0	0	+	+
21	5	0	+	0	+	+	+
21	6	0	4	0	1	3	4
21	7	+	3	0	1	+	3
22	2	0	1	0	3	1	3
22	3	0	3	0	1	+	3
22	4	0	2	0	1	0	2
22	5	0	+	0	2	+	2
22	6	+	3	0	2	+	4
22	7	0	3	0	3	1	4
23	2	0	0	0	0	+	+

23	3	0	0	0	0	+	+
23	4	+	+	0	0	1	1
23	5	+	0	0	0	1	1
23	6	+	1	0	2	2	4
23	7	1	2	0	1	1	4
24	2	0	1	0	2	+	2
24	3	0	+	0	1	+	1
24	4	0	+	0	0	2	2
24	5	0	+	+	2	1	2
24	6	0	1	0	1	2	2
24	7	0	3	0	2	3	5
25	2	0	0	0	0	+	+
25	3	0	2	0	0	+	2
25	4	0	2	0	1	1	2
25	5	0	0	0	0	+	+
25	6	+	1	0	1	4	4
25	7	1	2	0	1	2	3
26	2	0	0	0	1	0	1
26	3	0	0	0	0	2	2
26	4	0	+	0	0	3	3
26	5	0	0	0	1	1	1
26	6	1	1	0	+	3	3
26	7	1	2	0	1	3	3
27	2	1	+	0	0	1	1
27	3	0	0	0	0	2	2
27	4	0	1	0	0	2	2
27	5	0	0	0	0	2	2
27	6	0	1	0	2	4	4
27	7	0	1	0	2	5	5
28	2	0	+	0	2	1	2
28	3	0	0	0	0	2	2
28	4	0	0	0	2	+	2
28	5	0	+	0	2	1	2
28	6	0	1	0	3	0	3
28	7	0	3	0	3	+	4
29	2	0	+	0	2	1	2
29	3	0	+	0	2	1	2
29	4	0	0	0	1	1	1
29	5	+	+	0	1	1	2
29	6	0	+	0	4	+	4
29	7	0	+	0	3	+	3
30	2	0	+	0	0	3	3
30	3	0	+	0	0	3	3
30	4	0	3	0	1	2	4
30	5	0	1	0	1	2	3
30	6	0	1	0	4	2	4
30	7	0	1	0	3	1	3
31	2	0	2	0	2	1	3
31	3	0	1	0	0	1	2

31	4	0	+	0	1	2	2
31	5	0	0	0	1	2	3
31	6	0	+	0	3	+	3
31	7	0	+	0	3	+	3
32	1	0	0	0	0	0	3
32	2	0	+	0	0	0	2
32	3	+	1	0	0	0	2
32	4	0	+	0	0	0	1
32	5	0	1	0	0	+	3
32	6	0	1	0	0	0	4
32	7	0	2	0	0	4	5
33	1	0	+	0	0	1	2
33	2	0	+	0	0	+	2
33	3	0	+	0	0	+	2
33	4	0	0	0	0	4	5
33	5	+	0	0	0	4	5
33	6	0	2	0	0	5	5
33	7	0	3	0	0	3	4
34	2	0	+	0	2	2	2
34	3	0	+	0	1	2	2
34	4	0	+	0	2	1	2
34	5	0	+	0	1	1	1
34	6	0	0	0	1	1	1
34	7	0	0	0	1	1	1
35	2	0	0	0	2	+	2
35	3	0	0	+	2	+	2
35	4	0	+	+	2	+	2
35	5	0	+	0	2	+	2
35	6	0	6	1	1	5	6
35	7	0	5	1	1	5	6
36	2	0	+	0	0	1	1
36	3	0	+	0	0	1	1
36	4	1	+	0	1	1	2
36	5	1	+	0	+	1	2
36	6	1	3	0	1	5	5
36	7	1	3	0	3	4	5
37	2	0	+	0	2	+	2
37	3	0	+	+	+	1	1
37	4	0	+	0	1	1	2
37	5	0	+	0	1	+	1
37	6	0	+	+	4	+	4
37	7	0	1	+	1	5	5
38	2	+	+	0	2	1	2
38	3	0	+	0	1	2	2
38	4	0	+	0	1	3	3
38	5	1	0	0	0	1	2
38	6	1	2	0	2	4	5
38	7	0	3	0	2	4	5
39	2	0	0	0	0	4	4

z	3	0	0	0	0	2	2
39	4	0	1	0	1	2	2
39	5	0	+	0	0	1	1
39	6	0	1	0	2	2	3
39	7	+	2	0	2	2	4
40	2	0	1	0	+	+	1
40	3	0	2	0	0	1	3
40	4	+	1	0	0	1	4
40	5	1	2	0	1	1	3
40	6	0	1	0	2	2	4
40	7	0	2	0	2	2	4

APPENDIX E

SPECIES LIST

Listing of all species identified during field surveys; measurements provide are means of height and average diameter (averaged from cross-sectional measures of canopy diameter).

Species	Plot #																	
	2			3			4			5			6			7		
	H (cm)	D (cm)	#	H (cm)	D (cm)	#	H (cm)	D (cm)	#	H (cm)	D (cm)	#	H (cm)	D (cm)	#	H (cm)	D (cm)	#
Ambrosia dumosa	-	-	-	-	-	-	-	-	-	70	112.32	14	50.43	69.21	140	64.59	89.21	85
Amsinckia tessellata	<10			<10			<10			<10			<10			<10		
Bebbia juncea	-	-	-	-	-	-	<10			55	83	10	65	77.5	2	26.67	33.33	3
Brassica tournefortii	4.76		188	5.73		368	4.8		225	17.46		63	7.93		203	4.84		286
Bromus rubens	<10			<10			<10			<10			<10			<10		
Camissonia brevipes	<10			<10			<10			<10			<10			<10		
Cryptantha spp	<10			<10			<10			<10			<10			<10		
Datura wrightii	-	-	-	<10			-	-	-	-	-	-	-	-	-	-	-	-
Encelia farinosa	-	-	-	100	275	1	67.5	67.5	4	75	97.92	12	49.63	70.07	267	66.51	83.80	83
Enceliopsis argophylla	<10			<10			-	-	-	<10			-	-	-	<10		
Ephedra spp	-	-	-	-	-	-	-	-	-	<10			<10			<10		
Eriogonum deflatum		9.15	236		6.64	614		7.84	523		13.28	229		18.96	48		15.71	21
Eriogonum inflatum	-	-	-	-	-	-	-	-	-	30	30	1	<10			<10		
Eriogonum spp.	<10			<10			<10			<10			<10			<10		
Erodium cicutarium	<10			-	-	-	<10			-	-	-	<10			<10		
Eschscholzia glyptosperma	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<10		
Eucnide urens	46.92	70.77	13	46.8	65	25	54.76	80.48	21	52.30	83.54	37	-	-	-	30	35	1
Geraea canescens	-	-	-	-	-	-	-	-	-	-	-	-	<10			<10		
Gilia latifolia	-	-	-	-	-	-	-	-	-	<10			-	-	-	-	-	-
Heliotropium curassavicum	-	-	-	-	-	-	<10			<10			<10			-	-	-
Larrea tridentata	-	-	-	-	-	-	140	210	1	90	117.86	7	87.60	108.43	127	85.75	108.45	186
Lipidium fremontii	-	-	-	<10			<10			<10			<10			<10		
Lupinus arizonicus	<10			<10			<10			<10			<10			<10		
Lupinus sparsiflorus	-	-	-	<10			<10			-	-	-	-	-	-	<10		
Mentzelia tricuspis	-	-	-	<10			-	-	-	<10			<10			<10		
Nicotiana obtusifolia	<10			<10			<10			<10			<10			<10		
Opuntia acanthocarpa	-	-	-	-	-	-	-	-	-	-	-	-	26.67	26.67	3	-	-	-
Opuntia basilarus	-	-	-	-	-	-	-	-	-	35	32.5	1	60	61.46	12	37.06	39.71	17
Opuntia echinocarpa	-	-	-	-	-	-	-	-	-	-	-	-	76.67	85	3	20	45	1
Osilia spp	-	-	-	-	-	-	-	-	-	<10			-	-	-	-	-	-
Perityle emoryi	-	-	-	-	-	-	-	-	-	<10			-	-	-	-	-	-
Peucephyllum schottii	-	-	-	-	-	-	50	95	1	54	73	5	130	170	2	-	-	-
Phacelia crenulata	<10			<10			<10			<10			<10			<10		
Phacelia spp	-	-	-	-	-	-	<10			<10			<10			<10		
Plantago ovata	-	-	-	-	-	-	-	-	-	<10			<10			<10		
Pluchea sericea	-	-	-	-	-	-	-	-	-	-	-	-	<10			-	-	-
Psorothamnus fremontii	-	-	-	-	-	-	-	-	-	-	-	-	40	49	5	32.5	37.5	8
Salsola tragus	<10			<10			<10			<10			<10			-	-	-

Species	Plot #																	
	2			3			4			5			6			7		
	H (cm)	D (cm)	#	H (cm)	D (cm)	#	H (cm)	D (cm)	#	H (cm)	D (cm)	#	H (cm)	D (cm)	#	H (cm)	D (cm)	#
Schismus spp	<10			<10			<10			<10			<10			<10		
Spharalcea ambigua	-	-	-	70	77	10	94	107.4	25	76.67	85	6	72.5	103.75	8	60	50	1
Stephanomeria pauciflora	-	-	-	-	-	-	<10			<10			<10			<10		
Tamarix aphylla	-	-	-	-	-	-	185	190	2	-	-	-	-	-	-	-	-	-
Tamarix ramosissima	11.50		876	35.37		162	29.43		194	21.05		271	35.58		103	33.41		88
Xylorhiza tortifolia	-	-	-	-	-	-	-	-	-	-	-	-	<10			<10		

APPENDIX F

PHYSICAL CHARACTERISTICS OF PLOTS

Physical site characteristics (slope, aspect, etc) of all plots.

Tran#	Plot#	Direction	Aspect	Plot Slope	Shoreline		Tran#	Plot#	Direction	Aspect	Plot Slope	Shoreline
1	2	50	225	12	Concave		1	2	46	192	15	Convex
1	3	50	230	13	Concave		21	3	46	192	15	Convex
1	4	50	230	19	Concave		21	4	46	192	20	Convex
1	5	50	230	8	Concave		21	5	46	192	12	Convex
1	6	358	128	5	Concave		21	6	46	192	5	Convex
1	7	358	106	2	Concave		21	7	46	192	4	Convex
2	2	192	140	20	Convex		22	2	80	250	3	Concave
2	3	192	156	18	Convex		22	3	80	250	4	Concave
2	4	192	186	10	Convex		22	4	80	250	8	Concave
2	5	192	206	1	Convex		22	5	80	250	10	Concave
2	6	192	230	2	Convex		22	6	80	250	8	Concave
2	7	192	263	5	Convex		22	7	80	250	2	Concave
3	2	305	130	4	Concave		23	2	86	236	8	Convex
3	3	305	101	10	Concave		23	3	86	236	10	Convex
3	4	305	130	12	Concave		23	4	86	236	8	Convex
3	5	305	116	10	Concave		23	5	86	236	6	Convex
3	6	305	110	20	Concave		23	6	86	236	12	Convex
3	7	305	108	5	Concave		23	7	86	236	5	Convex
4	2	348	146	5	Convex		24	2	108	288	5	Convex
4	3	348	146	8	Convex		24	3	108	288	13	Convex
4	4	348	146	6	Convex		24	4	108	316	15	Convex
4	5	348	146	10	Convex		24	5	108	360	6	Convex
4	6	348	146	1	Convex		24	6	108	360	17	Convex
4	7	348	146	3	Convex		24	7	108	360	20	Convex
5	2	28	212	15	Convex		25	2	32	202	12	Concave
5	3	28	212	30	Convex		25	3	32	202	7	Concave
5	4	28	212	30	Convex		25	4	32	202	4	Concave
5	5	28	212	30	Convex		25	5	32	202	13	Concave
5	6	28	212	30	Convex		25	6	32	202	15	Concave
5	7	28	212	30	Convex		25	7	32	202	2	Concave
6	2	358	182	12	Concave		26	2	36	247	6	Convex
6	3	358	182	7	Concave		26	3	36	247	11	Convex
6	4	358	182	5	Concave		26	4	36	246	5	Convex
6	5	358	182	13	Concave		26	5	36	247	2	Convex

6	6	358	182	22	Concave		26	6	36	247	2	Convex
6	7	358	182	3	Concave		26	7	36	247	2	Convex
7	2	244	54	15	Concave		27	2	66	226	16	Concave
7	3	244	54	20	Concave		27	3	66	226	8	Concave
7	4	244	54	20	Concave		27	4	66	226	18	Concave
7	5	244	54	25	Concave		27	5	66	226	12	Concave
7	6	244	54	2	Concave		27	6	66	226	30	Concave
7	7	244	54	4	Concave		27	7	66	226	30	Concave
8	2	340	146	5	Concave		28	2	60	240	20	Convex
8	3	340	146	20	Concave		28	3	60	240	25	Convex
8	4	340	146	15	Concave		28	4	60	240	25	Convex
8	5	340	146	10	Concave		28	5	60	240	20	Convex
8	6	340	146	30	Concave		28	6	60	240	8	Convex
8	7	340	146	30	Concave		28	7	60	240	10	Convex
9	2	328	142	5	Concave		29	2	22	218	5	Convex
9	3	328	142	4	Concave		29	3	22	218	8	Convex
9	4	328	142	10	Concave		29	4	22	218	15	Convex
9	5	328	142	15	Concave		29	5	22	218	25	Convex
9	6	328	142	25	Concave		29	6	22	218	5	Convex
9	7	328	142	30	Concave		29	7	22	218	20	Convex
10	2	300	70	3	Convex		30	2	14	194	16	Concave
10	3	300	130	15	Convex		30	3	14	194	20	Concave
10	4	300	130	13	Convex		30	4	14	194	20	Concave
10	5	300	130	10	Convex		30	5	14	194	20	Concave
10	6	300	130	20	Convex		30	6	14	194	25	Concave
10	7	300	130	30	Convex		30	7	14	194	30	Concave
11	2	248	96	10	Concave		31	2	216	25	25	Concave
11	3	248	96	15	Concave		31	3	216	25	28	Concave
11	4	248	96	15	Concave		31	4	216	25	28	Concave
11	5	248	96	12	Concave		31	5	216	25	20	Concave
11	6	248	96	20	Concave		31	6	216	25	30	Concave
11	7	248	96	25	Concave		31	7	216	25	30	Concave
12	2	240	60	5	Concave		32	2	192	12	12	Concave
12	3	240	60	15	Concave		32	3	192	12	20	Concave
12	4	240	60	8	Concave		32	4	192	12	18	Concave
12	5	240	60	15	Concave		32	5	192	12	15	Concave
12	6	240	60	2	Concave		32	6	192	12	10	Concave
12	7	240	60	5	Concave		32	7	192	12	20	Concave
13	2	206	24	4	Concave		33	2	300	120	15	Convex
13	3	206	346	10	Concave		33	3	300	120	15	Convex
13	4	206	326	6	Concave		33	4	300	120	20	Convex
13	5	206	220	5	Concave		33	5	300	120	20	Convex
13	6	206	232	4	Concave		33	6	300	120	25	Convex
13	7	206	192	8	Concave		33	7	300	120	25	Convex
14	2	146	312	20	Concave		34	2	174	11	7	Convex
14	3	146	312	30	Concave		34	3	174	11	13	Convex
14	4	146	312	30	Concave		34	4	174	11	8	Convex

14	5	146	312	15	Concave		34	5	174	11	2	Convex
14	6	146	312	1	Concave		34	6	140	320	8	Convex
14	7	146	312	-1	Concave		34	7	140	320	10	Convex
15	2	60	240	15	Concave		35	2	194	10	12	Convex
15	3	60	240	10	Concave		35	3	194	10	5	Convex
15	4	60	240	10	Concave		35	4	194	10	3	Convex
15	5	60	240	15	Concave		35	5	194	10	4	Convex
15	6	60	240	3	Concave		35	6	194	10	2	Convex
15	7	60	240	2	Concave		35	7	194	10	1	Convex
16	2	48	232	12	Concave		36	2	246	64	10	Concave
16	3	48	232	20	Concave		36	3	246	64	8	Concave
16	4	48	232	15	Concave		36	4	246	64	10	Concave
16	5	48	232	15	Concave		36	5	246	64	9	Concave
16	6	48	232	25	Concave		36	6	246	64	10	Concave
16	7	48	232	30	Concave		36	7	246	350	8	Concave
17	2	56	204	20	Concave		37	2	152	338	3	Convex
17	3	56	204	30	Concave		37	3	152	338	18	Convex
17	4	56	204	30	Concave		37	4	152	338	13	Convex
17	5	56	204	3	Concave		37	5	152	338	15	Convex
17	6	56	204	25	Concave		37	6	152	338	11	Convex
17	7	56	204	8	Concave		37	7	152	338	18	Convex
18	2	328	148	30	Concave		38	2	64	256	12	Concave
18	3	328	148	30	Concave		38	3	64	256	10	Concave
18	4	328	148	30	Concave		38	4	64	256	25	Concave
18	5	328	148	5	Concave		38	5	64	256	12	Concave
18	6	328	148	28	Concave		38	6	64	256	30	Concave
18	7	328	148	5	Concave		38	7	64	256	30	Concave
19	2	92	292	15	Concave		39	2	68	218	10	Concave
19	3	92	292	15	Concave		39	3	68	218	20	Concave
19	4	92	292	20	Concave		39	4	68	218	10	Concave
19	5	92	292	6	Concave		39	5	68	218	4	Concave
19	6	92	292	5	Concave		39	6	42	190	12	Concave
19	7	92	292	4	Concave		39	7	42	190	6	Concave
20	2	28	210	22	Convex		40	2	166	340	20	Concave
20	3	28	210	15	Convex		40	3	166	340	25	Concave
20	4	28	210	25	Convex		40	4	166	340	25	Concave
20	5	28	210	5	Convex		40	5	166	340	20	Concave
20	6	28	210	3	Convex		40	6	166	340	30	Concave
20	7	28	210	2	Convex		40	7	166	340	30	Concave

APPENDIX G

ROCK COMPOSITION OF EACH PLOT

Rock cover for all plots by percent cover (see Appendix C for description of rock cover classes).

Tran#	Plot#	Gravel	Cobble	Boulders		Tran#	Plot#	Gravel	Cobble	Boulders
1	2	0	0	0		21	2	5	3	+
1	3	+	0	0		21	3	5	4	1
1	4	2	2	0		21	4	5	3	2
1	5	2	2	2		21	5	5	2	2
1	6	2	3	4		21	6	2	1	+
1	7	2	3	4		21	7	1	1	2
2	2	2	2	2		22	2	0	0	0
2	3	0	2	2		22	3	2	3	+
2	4	0	2	2		22	4	1	2	+
2	5	2	2	0		22	5	3	3	+
2	6	0	0	0		22	6	+	1	2
2	7	0	0	0		22	7	0	+	+
3	2	1	3	6		23	2	1	4	1
3	3	2	3	6		23	3	1	4	2
3	4	3	0	6		23	4	2	2	4
3	5	2	2	5		23	5	4	2	3
3	6	+	0	0		23	6	2	1	2
3	7	+	0	0		23	7	4	2	1
4	2	5	5	+		24	2	1	1	2
4	3	3	3	2		24	3	3	3	3
4	4	4	4	2		24	4	1	2	5
4	5	3	3	3		24	5	1	3	4
4	6	1	3	1		24	6	2	1	+
4	7	1	3	1		24	7	1	2	1
5	2	5	5	3		25	2	3	1	0
5	3	1	1	5		25	3	4	3	+
5	4	2	3	3		25	4	2	3	+
5	5	0	2	5		25	5	5	3	0
5	6	0	2	4		25	6	2	2	+
5	7	0	2	4		25	7	3	3	+
6	2	0	0	0		26	2	2	2	2
6	3	1	4	0		26	3	3	3	5
6	4	3	0	0		26	4	2	4	5
6	5	4	0	0		26	5	3	4	3

6	6	3	1	0		26	6	3	3	2
6	7	2	1	0		26	7	5	4	2
7	2	0	+	0		27	2	3	2	0
7	3	+	1	0		27	3	5	3	0
7	4	0	+	4		27	4	3	3	1
7	5	1	1	1		27	5	5	5	0
7	6	+	2	+		27	6	1	3	+
7	7	1	+	+		27	7	+	2	3
8	2	+	0	0		28	2	1	2	2
8	3	+	+	5		28	3	1	3	3
8	4	+	1	5		28	4	2	3	3
8	5	0	0	3		28	5	2	3	3
8	6	0	+	2		28	6	+	+	0
8	7	0	0	2		28	7	1	1	1
9	2	0	0	0		29	2	+	1	5
9	3	0	+	+		29	3	2	2	4
9	4	+	1	1		29	4	3	2	+
9	5	0	0	1		29	5	+	1	4
9	6	0	0	+		29	6	1	2	1
9	7	+	+	+		29	7	1	2	4
10	2	2	+	0		30	2	4	1	0
10	3	2	3	2		30	3	5	1	+
10	4	2	3	1		30	4	2	+	0
10	5	2	2	1		30	5	4	1	+
10	6	2	4	+		30	6	1	2	2
10	7	1	4	2		30	7	+	1	2
11	2	2	2	1		31	2	3	+	0
11	3	2	3	+		31	3	2	+	+
11	4	4	3	1		31	4	2	+	+
11	5	4	4	2		31	5	2	+	2
11	6	2	3	1		31	6	1	2	4
11	7	3	3	2		31	7	1	3	3
12	2	1	3	3		32	2	1	+	0
12	3	2	3	1		32	3	4	4	2
12	4	2	+	0		32	4	4	4	2
12	5	2	4	+		32	5	3	4	2
12	6	3	4	1		32	6	1	3	+
12	7	2	3	+		32	7	2	4	1
13	2	0	0	0		33	2	2	3	3
13	3	3	1	+		33	3	2	2	3
13	4	3	2	1		33	4	1	2	4
13	5	0	1	+		33	5	2	3	3
13	6	2	1	0		33	6	2	3	3
13	7	0	0	0		33	7	2	3	3
14	2	3	2	1		34	2	2	2	1
14	3	3	2	+		34	3	1	1	3
14	4	2	2	+		34	4	2	2	2
14	5	2	2	1		34	5	3	1	2

14	6	2	3	+		34	6	1	1	2
14	7	2	2	0		34	7	1	+	+
15	2	+	+	0		35	2	3	4	3
15	3	1	3	3		35	3	4	2	5
15	4	1	3	2		35	4	2	2	4
15	5	2	2	3		35	5	2	2	5
15	6	2	2	1		35	6	0	0	0
15	7	5	3	1		35	7	1	1	1
16	2	1	0	0		36	2	5	3	0
16	3	3	1	+		36	3	5	4	3
16	4	4	1	+		36	4	4	3	3
16	5	3	3	+		36	5	2	3	4
16	6	1	1	0		36	6	3	4	0
16	7	1	2	4		36	7	2	3	2
17	2	+	1	+		37	2	1	4	4
17	3	2	3	5		37	3	0	1	5
17	4	+	2	5		37	4	1	2	3
17	5	4	2	+		37	5	2	1	2
17	6	+	2	2		37	6	1	4	2
17	7	2	3	2		37	7	0	1	3
18	2	1	2	+		38	2	2	2	2
18	3	5	5	+		38	3	4	2	2
18	4	5	5	2		38	4	4	2	3
18	5	4	2	+		38	5	2	4	2
18	6	2	4	2		38	6	2	3	3
18	7	1	5	2		38	7	1	3	3
19	2	1	1	2		39	2	0	5	+
19	3	1	3	5		39	3	2	3	0
19	4	1	2	4		39	4	2	3	+
19	5	2	3	4		39	5	3	3	+
19	6	5	0	0		39	6	1	3	3
19	7	4	2	1		39	7	1	3	3
20	2	2	3	5		40	2	1	1	5
20	3	3	2	4		40	3	3	3	2
20	4	3	3	1		40	4	2	2	2
20	5	2	5	2		40	5	2	3	5
20	6	4	2	+		40	6	1	1	5
20	7	1	+	0		40	7	1	2	4

APPENDIX H

SOIL DATA

Soil data from analysis of soil samples collected during field surveys.

Tran #	plot#	pH	%SOM	% sand	% clay	% silt	N Conc
1	2	7.55	0.0118	90.0	2.5	7.5	0.8968
1	3	7.95	0.0098	95.0	1.3	3.8	0.4535
1	4	8.20	0.0080	93.8	1.2	5.0	0.3994
1	5	8.35	0.0092	97.5	2.5	0.0	0.3102
1	6	7.60	0.0148	80.0	5.0	15.0	0.7968
1	7	7.70	0.0176	81.3	5.0	13.8	1.0239
2	2	8.05	0.0052	97.5	1.3	1.3	0.1426
2	3	8.00	0.0077	90.0	1.2	8.7	0.1804
2	4	7.60	0.0079	90.0	2.5	7.5	0.2399
2	5	8.20	0.0081	97.5	1.2	1.2	0.2426
2	6	7.80	0.0123	91.3	2.5	6.2	0.5967
2	7	7.85	0.0124	92.5	2.5	5.0	0.6724
3	2	7.60	0.0263	60.0	6.2	33.7	1.4780
3	3	7.65	0.0156	78.8	3.7	17.5	0.8130
3	4	8.45	0.0070	93.8	1.2	5.0	0.1318
3	5	8.65	0.0072	97.5	0.0	2.5	0.1156
3	6	8.10	0.0077	93.8	2.5	3.7	0.2967
3	7	8.05	0.0171	76.3	6.2	17.5	0.7995
4	2	8.20	0.0106	98.8	0.0	1.3	0.1210
4	3	8.05	0.0165	87.5	2.5	10.0	0.5129
4	4	8.15	0.0125	90.0	1.2	8.7	0.4751
4	5	8.65	0.0116	97.5	0.0	2.5	0.1453
4	6	7.90	0.0268	73.8	10.0	16.3	0.7292
4	7	8.05	0.0170	75.0	6.2	18.7	0.5535
5	2	7.45	0.0129	80.0	2.5	17.5	0.8454
5	3	7.60	0.0132	85.0	2.5	12.5	0.7670
5	4	8.15	0.0098	95.0	2.5	2.5	0.4778
5	5	8.45	0.0115	93.8	1.2	5.0	0.2696
5	6	7.65	0.0332	80.0	3.8	16.3	3.9191

5	7	7.80	0.0176	82.5	3.7	13.7	0.9265
6	2	8.25	0.0045	98.8	1.2	0.0	0.1803
6	3	8.35	0.0059	97.5	1.2	1.2	0.1616
6	4	8.40	0.0064	96.3	2.5	1.3	0.2976
6	5	8.45	0.0041	98.8	1.2	0.0	0.1403
6	6	8.45	0.0059	95.0	2.5	2.5	0.1803
6	7	8.30	0.0058	96.3	2.5	1.2	0.1156
7	2	7.80	0.0342	47.5	0.0	52.5	0.5065
7	3	7.55	0.0449	37.5	0.0	62.5	0.2565
7	4	7.50	0.0437	27.5	2.5	70.0	0.2751
7	5	7.45	0.0233	72.5	7.5	20.0	0.2060
7	6	7.70	0.0225	76.3	6.2	17.5	0.2113
7	7	7.55	0.0104	90.0	1.3	8.8	0.0916
8	2	8.15	0.0047	91.3	2.5	6.2	0.1847
8	3	8.20	0.0037	93.8	2.5	3.7	0.1369
8	4	8.10	0.0063	91.3	3.7	5.0	0.1369
8	5	8.20	0.0041	92.5	2.5	5.0	0.0890
8	6	8.25	0.0048	86.3	2.5	11.2	0.0518
8	7	8.25	0.0031	93.8	2.5	3.7	0.0810
9	2	8.20	0.0054	92.5	3.7	3.7	0.1138
9	3	8.15	0.0077	88.8	5.0	6.2	0.0662
9	4	8.25	0.0077	91.3	5.0	3.7	0.1191
9	5	8.20	0.0041	92.5	2.5	5.0	0.0278
9	6	8.25	0.0047	93.8	1.2	5.0	0.0677
9	7	8.30	0.0021	96.3	1.2	2.5	0.0783
10	2	8.00	0.0061	92.5	2.5	5.0	0.1747
10	3	8.35	0.0018	97.5	1.3	1.3	0.0662
10	4	8.25	0.0017	97.5	1.2	1.2	0.0874
10	5	8.30	0.0021	97.5	1.3	1.3	0.1879
10	6	8.10	0.0031	95.0	2.5	2.5	0.2672
10	7	8.35	0.0029	97.5	1.3	1.3	0.1165
11	2	7.80	0.0031	93.8	2.5	3.7	0.1429
11	3	8.00	0.0028	97.5	1.3	1.3	0.1667
11	4	7.40	0.0120	80.0	5.0	15.0	0.6163
11	5	8.35	0.0022	97.5	1.3	1.3	0.0715
11	6	8.20	0.0101	81.3	6.3	12.5	0.2249
11	7	8.10	0.0056	93.8	2.5	3.8	0.2672
12	2	8.40	0.0029	97.5	1.2	1.2	0.0900
12	3	8.15	0.0069	90.0	3.7	6.2	0.2091
12	4	8.50	0.0022	96.3	1.2	2.5	0.1112
12	5	8.70	0.0034	97.5	1.2	1.2	0.0662

12	6	8.40	0.0065	92.5	3.8	3.8	0.2196
12	7	8.25	0.0045	90.0	3.7	6.2	0.1033
13	2	7.70	0.0153	61.3	3.8	35.0	1.0739
13	3	8.40	0.0028	95.0	1.3	3.8	0.1376
13	4	8.40	0.0030	96.3	0.0	3.7	0.1509
13	5	8.05	0.0143	71.3	7.5	21.2	0.6269
13	6	8.25	0.0051	92.5	2.5	5.0	0.2646
13	7	7.80	0.0065	91.3	1.2	7.5	0.2117
14	2	8.55	0.0008	98.8	0.0	1.3	0.1297
14	3	8.45	0.0024	98.8	0.0	1.3	0.1033
14	4	8.65	0.0032	98.8	0.0	1.2	0.1138
14	5	8.60	0.0021	98.8	0.0	1.2	0.0821
14	6	8.00	0.0117	80.0	6.3	13.8	0.5264
14	7	8.05	0.0109	85.0	5.0	10.0	0.5105
15	2	7.85	0.0045	93.8	1.2	5.0	0.2523
15	3	8.10	0.0091	85.0	1.3	13.8	0.3023
15	4	8.20	0.0058	93.8	1.2	5.0	0.2011
15	5	8.50	0.0023	97.5	0.0	2.5	0.1535
15	6	8.20	0.0041	98.8	0.0	1.2	0.1958
15	7	8.60	0.0077	96.3	1.2	2.5	0.4365
16	2	8.30	0.0030	98.8	1.3	0.0	0.0551
16	3	8.25	0.0037	96.3	1.2	2.5	0.1190
16	4	8.35	0.0023	97.5	1.2	1.2	0.2245
16	5	8.45	0.0031	97.5	1.2	1.2	0.0662
16	6	8.30	0.0025	97.5	1.2	1.2	0.1384
16	7	8.25	0.0046	96.3	1.3	2.5	0.2606
17	2	8.10	0.0069	95.0	1.2	3.7	0.3023
17	3	8.30	0.0049	98.8	1.2	0.0	0.0412
17	4	8.00	0.0334	62.5	2.5	35.0	0.0579
17	5	8.40	0.0080	95.0	2.5	2.5	0.0579
17	6	8.15	0.0061	96.3	1.2	2.5	0.1023
17	7	8.00	0.0170	82.5	7.5	10.0	0.4495
18	2	8.00	0.0123	95.0	1.2	3.7	0.3384
18	3	8.20	0.0111	92.5	1.2	6.2	0.3218
18	4	8.65	0.0067	97.5	1.2	1.2	0.1495
18	5	8.65	0.0063	98.8	0.0	1.2	0.0829
18	6	8.10	0.0120	90.0	5.0	5.0	0.4523
18	7	8.15	0.0126	86.2	7.5	6.3	0.4134
19	2	8.05	0.0102	77.5	6.2	16.2	0.2690
19	3	8.15	0.0054	92.5	1.3	6.3	0.1190
19	4	7.95	0.0114	87.5	7.5	5.0	0.1162

19	5	8.40	0.0034	98.8	0.0	1.2	0.2245
19	6	8.15	0.0083	95.0	1.2	3.7	0.7829
19	7	7.70	0.0172	92.5	1.2	6.2	1.2134
20	2	8.40	0.0029	98.8	0.0	1.2	0.0829
20	3	8.45	0.0037	98.8	1.2	0.0	0.0745
20	4	8.40	0.0069	97.5	1.3	1.3	0.3440
20	5	8.10	0.0050	98.8	0.0	1.2	0.1079
20	6	8.05	0.0073	95.0	1.3	3.8	0.3912
20	7	7.90	0.0093	93.8	1.2	5.0	0.4440
21	2	8.25	0.0032	98.8	1.3	0.0	0.0894
21	3	8.70	0.0040	96.3	2.5	1.3	0.1412
21	4	8.35	0.0032	97.5	1.3	1.3	0.0690
21	5	8.25	0.0051	92.5	1.2	6.2	0.1468
21	6	8.10	0.0110	95.0	1.3	3.8	0.9995
21	7	8.15	0.0115	83.8	2.5	13.7	0.5745
22	2	7.50	0.0251	77.5	3.7	18.7	1.4642
22	3	7.55	0.0139	81.3	2.5	16.3	0.6393
22	4	7.65	0.0073	93.7	1.3	5.0	0.2782
22	5	8.20	0.0046	96.3	1.2	2.5	0.1755
22	6	8.10	0.0133	93.8	1.3	5.0	0.5421
22	7	8.00	0.0077	95.0	1.3	3.8	0.2699
23	2	8.00	0.0053	97.5	1.3	1.3	0.0755
23	3	8.60	0.0039	98.7	0.0	1.3	0.1227
23	4	8.50	0.0053	93.7	1.3	5.0	0.2310
23	5	8.80	0.0033	97.5	1.3	1.3	0.0505
23	6	7.90	0.0144	88.7	2.5	8.8	0.5143
23	7	8.15	0.0080	90.0	2.5	7.5	0.3060
24	2	8.00	0.0168	86.3	2.5	11.3	0.9809
24	3	8.05	0.0165	75.0	13.8	11.3	0.4615
24	4	8.85	0.0071	92.5	1.2	6.2	0.0505
24	5	8.65	0.0084	91.3	5.0	3.7	0.0394
24	6	7.95	0.0267	70.0	11.3	18.8	0.2921
24	7	8.40	0.0200	77.5	7.5	15.0	0.6810
25	2	8.70	0.0055	96.3	2.5	1.2	0.1588
25	3	8.65	0.0040	96.3	2.5	1.3	0.1505
25	4	8.70	0.0064	91.3	3.8	5.0	0.0699
25	5	8.65	0.0044	96.2	2.5	1.3	0.0394
25	6	8.55	0.0097	95.0	3.7	1.2	0.3255
25	7	8.70	0.0099	90.0	3.8	6.3	0.4504
26	2	8.15	0.0073	92.5	1.3	6.3	0.3282
26	3	9.10	0.0040	93.7	3.8	2.5	0.0449

26	4	8.60	0.0070	95.0	2.5	2.5	0.1560
26	5	8.50	0.0062	96.2	1.3	2.5	0.1199
26	6	8.20	0.0088	93.8	1.3	5.0	0.7948
26	7	8.30	0.0129	91.3	2.5	6.2	0.5615
27	2	8.55	0.0063	96.3	0.0	3.7	0.2144
27	3	9.15	0.0065	93.8	1.2	5.0	0.0422
27	4	8.75	0.0086	88.8	3.7	7.5	0.0838
27	5	8.65	0.0066	93.8	1.2	5.0	0.1283
27	6	8.55	0.0197	78.7	3.8	17.5	0.3671
27	7	8.45	0.0205	73.8	6.3	20.0	0.4116
28	2	8.30	0.0032	97.5	1.2	1.2	0.1429
28	3	8.55	0.0036	97.5	1.3	1.3	0.1776
28	4	8.40	0.0076	91.3	5.0	3.7	0.2709
28	5	8.65	0.0042	96.2	2.5	1.3	0.2656
28	6	8.05	0.0101	93.8	3.7	2.5	0.3963
28	7	8.10	0.0086	95.0	3.7	1.2	0.4683
29	2	7.85	0.0076	95.0	2.5	2.5	0.4816
29	3	7.95	0.0037	95.0	3.7	1.2	0.4870
29	4	8.25	0.0043	96.3	2.5	1.2	0.3109
29	5	8.10	0.0129	81.3	3.7	15.0	0.6603
29	6	7.65	0.0201	81.3	5.0	13.7	1.5217
29	7	7.95	0.0109	93.8	3.8	2.5	0.7136
30	2	8.35	0.0030	95.0	3.8	1.3	0.2645
30	3	8.45	0.0037	93.7	3.8	2.5	0.0916
30	4	8.40	0.0039	95.0	3.7	1.2	0.1794
30	5	8.45	0.0029	96.3	2.5	1.2	0.0358
30	6	8.25	0.0075	90.0	5.0	5.0	0.8017
30	7	8.00	0.0096	81.3	6.2	12.5	0.7136
31	2	8.20	0.0036	96.3	2.5	1.2	0.2884
31	3	8.35	0.0045	92.5	3.7	3.7	0.3363
31	4	8.30	0.0046	95.0	3.7	1.2	0.0916
31	5	8.55	0.0035	96.3	3.7	0.0	0.0252
31	6	8.00	0.0102	86.3	5.0	8.7	0.4507
31	7	8.05	0.0166	78.8	6.2	15.0	0.8868
32	2	7.50	0.0139	85.0	2.5	12.5	0.3230
32	3	7.90	0.0124	78.8	3.8	17.5	0.3044
32	4	7.85	0.0117	85.0	3.8	11.3	0.5358
32	5	8.45	0.0087	96.2	2.5	1.3	0.4081
32	6	7.95	0.0249	77.5	6.2	16.2	0.7272
32	7	7.85	0.0197	71.3	6.2	22.5	1.0224
33	2	8.00	0.0232	70.0	2.5	27.5	0.2645

33	3	8.15	0.0147	87.5	1.3	11.3	0.2991
33	4	7.90	0.0109	92.5	2.5	5.0	0.5304
33	5	7.85	0.0156	86.3	3.7	10.0	0.5969
33	6	8.00	0.0157	96.3	2.5	1.2	0.6129
33	7	7.95	0.0180	85.0	2.5	12.5	0.8921
34	2	8.05	0.0050	93.8	3.7	2.5	0.2229
34	3	8.25	0.0060	91.3	3.7	5.0	0.3563
34	4	8.25	0.0060	92.5	3.7	3.7	0.5243
34	5	8.15	0.0050	95.0	2.5	2.5	0.2176
34	6	7.90	0.0075	90.0	3.7	6.2	0.2043
34	7	7.75	0.0060	93.8	3.8	2.5	0.3723
35	2	7.75	0.0030	96.3	2.5	1.2	0.3963
35	3	8.10	0.0070	88.8	3.7	7.5	0.3669
35	4	8.15	0.0049	87.5	3.7	8.7	0.4096
35	5	8.10	0.0081	86.3	3.7	10.0	0.7136
35	6	7.65	0.0204	76.3	6.2	17.5	1.4150
35	7	7.55	0.0368	82.5	5.0	12.5	2.2018
36	2	8.05	0.0120	95.0	1.3	3.8	0.1749
36	3	8.05	0.0110	92.5	1.2	6.2	0.3083
36	4	8.50	0.0072	95.0	3.8	1.3	0.0736
36	5	8.45	0.0068	97.5	1.3	1.3	0.1349
36	6	8.40	0.0079	95.0	3.7	1.2	0.4123
36	7	8.05	0.0108	82.5	6.3	11.3	0.7003
37	2	7.35	0.0151	81.2	2.5	16.3	1.1905
37	3	7.80	0.0125	92.5	1.2	6.2	0.7357
37	4	7.85	0.0172	87.5	2.5	10.0	0.4606
37	5	8.15	0.0128	87.5	2.5	10.0	0.2073
37	6	7.75	0.0301	82.5	5.0	12.5	1.7897
37	7	7.85	0.0271	62.5	7.5	30.0	0.8637
38	2	8.30	0.0060	96.3	0.0	3.7	0.1610
38	3	8.40	0.0053	97.5	0.0	2.5	0.1910
38	4	8.05	0.0075	97.5	1.2	1.2	0.2427
38	5	8.25	0.0071	97.5	1.2	1.2	0.3190
38	6	7.90	0.0168	83.8	2.5	13.7	1.1633
38	7	7.50	0.0228	85.0	2.5	12.5	1.7788
39	2	8.55	0.0074	96.3	1.3	2.5	0.3886
39	3	8.40	0.0057	97.5	1.2	1.2	0.2318
39	4	8.30	0.0066	97.5	1.2	1.2	0.1588
39	5	8.85	0.0076	97.5	1.2	1.2	0.2588
39	6	8.00	0.0169	72.5	3.8	23.8	1.2509
39	7	7.85	0.0174	77.5	2.5	20.0	1.4645

40	2	7.75	0.0229	90.0	2.5	7.5	0.7765
40	3	8.35	0.0204	93.8	2.5	3.7	0.4524
40	4	8.20	0.0206	88.8	2.5	8.7	0.5750
40	5	8.10	0.0160	87.5	2.5	10.0	0.5314
40	6	7.65	0.0217	77.5	2.5	20.0	1.2532
40	7	8.00	0.0154	67.5	2.5	30.0	0.7330

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