Responses of native and non-native Mojave Desert winter annuals to soil disturbance and water additions

Alexis A. Suazo, Jessica E. Spencer, E. Cayenne Engel and Scott R. Abella

School of Environmental and Public Affairs, University of Nevada, Las Vegas 89154-4030, USA, e-mail: alex.suazo@unlv.edu

Introduction

In arid and semi-arid ecosystems water availability has a direct impact on plant recruitment, growth, and reproduction (Noy-Meir 1979). Changes in precipitation patterns due to climate change are expected to have significant effects on the distribution, structure, composition, and diversity of plant communities (Patrick et al. 2007, Robertson et al. 2010). Changes in precipitation may also increase the susceptibility of arid and semi-arid ecosystems to invasion by non-native invasive plant species (Weltzin et al. 2003).

World wide, non-native invasive plant species pose a major threat to biological conservation (Vitousek et al. 1996) and to the integrity of ecosystem functions and processes (D'Antonio and Vitousek 1992). In arid lands of the Southwestern USA, for example, invasion by non-native grasses has introduced a grass-fire cycle into these arid systems where fire has been rare due to low plant productivity and lack of continuous ground fuels (D'Antonio and Vitousek 1992, Brooks et al. 2004).

Generalizations about factors that enhance community invasibility have been elusive, but increases in resource availability and disturbance have been proposed to increase invasion success (Davis et al. 2000).

Here, we evaluate the resource availability hypothesis of plant invasion (Davis et al. 2000) to examine potential invasibility patterns of *Schismus* spp. (Mediterranean grass) and *Brassica tournefortii* (Sahara mustard) that may be influenced by climate change.

Methods

Study area

The study was conducted in Lake Mead National Recreation Area in Clark and Mohave Counties Nevada and Arizona USA. The total amount of winter growing-season precipitation recorded in October-January during the first year of the study (2007-2008) was 33 mm and 42 mm during the second year (2008-2009) (Western Regional Climate Center, Reno, NV).

Experimental Treatments

Five spatially independent sites were selected based on land management records of non-native species occurrences to evaluate experimental manipulations. At each site, we established 12 , 1 m x 1m plots in a four columns x three rows matrix. Treatment combinations were assigned using a random block design and consisted of water additions, soil disturbance, water + soil disturbance, and a control. Water (7 L / plot) was applied at two- week intervals during the winter rainy season using a watering can. Soil disturbance was applied once before plant emergence using a rake to disturb the upper soil surface. All treatments were implemented in two consecutive years.

Response variables

- Density of native and non-native winter annuals
- Silique production of *B. tournefortii*

Statistical methods

- Non-parametric analysis of variance and analysis of covariance
- Reduced major axis regression

Acknowledgements

The 2007 Nevada Conservation Corp group helped with plot set up, and University of Nevada Las Vegas undergraduate students with the Department of Environmental Studies and School of Life Sciences assisted with water applications. We thank Alice Newton, Kent Turner, and Carrie Norman for logistical support and Cheryl Vanier for statistical advice. This study was supported by a cooperative agreement between the National Park Service (Lake Mead National Recreation Area) and the University of Nevada Las Vegas, partially funded by the Clark County Multiple Species Habitat Conservation Plan.

Results

Non-native annual species

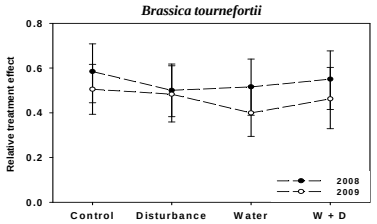

Fig. 1 Mean relative treatment effects on *Brassica tournefortii* seedling density as a function of time. Error bars represent 95 % CI.

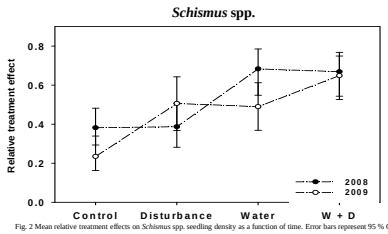

Fig. 2 Mean relative treatment effects on *Schismus* spp. seedling density as a function of time. Error bars represent 95 % CI.

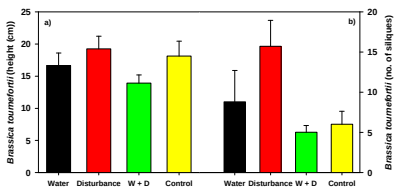

Fig. 3 Mean a) *Brassica tournefortii* height and b) number of siliques per plant in experimental patches. Error bars represent SE.

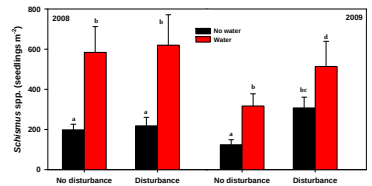

Fig. 4 Mean *Schismus* spp. density (seedlings m $^{-2}$) in plots where resource availability was manipulated through water additions and soil disturbance to evaluate effects on community invasibility. Different letters denote significant differences. Error bars represent SE.

Table 1. Analysis of covariance (ANCOVA) explaining treatment and *Brassica tournefortii* height (cm) relationships on silique production (no. of siliques per plant) . Plant height was used as a covariate.

Effect	DF	*F*	P-value
Water	1,4	0.13	0.733
Disturbance	1,4	1.14	0.346
Water + Disturbance	1,4	2.56	0.184
Height	1,149	174.95	**0.000**
Height x Water	1,149	0.00	0.952
Height x Disturbance	1,149	2.50	0.116
Height x Water x Disturbance	1, 149	4.35	**0.038**

Table 2. Non-parametric ANOVA for the habitat invasibility experiment testing effects of water addition and soil disturbance on *Schismus* spp. density (seedlings m^{-2}).

Treatment	DF (num, den)	*F*	P-value
Water	1, 112	11.0	**0.001**
Disturbance	1, 1.5	1.5	0.375
Water + Disturbance	1, 112	0.3	0.610
Year	1, inf	0.4	0.535
Water x Year	1, inf	1.7	0.186
Disturbance x Year	1, inf	8.4	**0.003**
Water x Disturbance x Year	1, inf	0.3	0.588

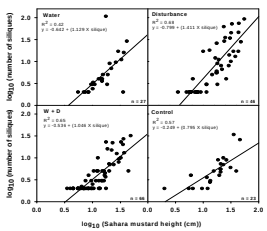

Fig. 5 Log-log plots of silique production (no. per plant) as a function of *Brassica tournefortii* height (cm) in experimental plots.

Table 3 Slopes obtained from reduced major axis (RMA) regression between height (log_{10} transformed) and water and soil manipulations for *Brassica tournefortii* silique production (log_{10} transformed).

Treatment	Slope	SE	95% CI	Pattern*	R^2
Control	1.055	0.151	0.740 ± 1.370	a	0.567
Water	1.738	0.264	1.194 ± 2.282	ab	0.422
Disturbance	1.714	0.147	1.417 ± 2.010	b	0.678
W + D	1.294	0.095	1.104 ± 1.485	ab	0.653

*Pattern denotes significant differences based on t-statistics for linear approximation in RMA

Native annual species

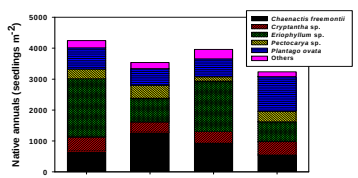

Fig. 6 Number native annual seedlings in experimental plots in 2009. Experimental treatments significantly influenced seedling emergence.

Table 4. Results from permutation MANOVA testing effects of water addition and soil disturbance on native annual abundance in 2009. P-values were generated from 999 permutations constrained within site.

Effect	DF	SS	MS	P (perm)	R^2
Water	1	0.590	0.590	**0.005**	0.0215
Disturbance	1	0.648	0.648	**0.017**	0.0236
Water x Disturbance	1	0.107	0.107	0.720	0.0039
Site	4	10.363			
Total	59	24.416			

Discussion

The spread and establishment of non-native plant species can be facilitated by the physical condition and resource availability of the invaded habitat (Davis et al. 2000). In this study, *B. tournefortii* and *Schismus* spp. responded differently to specific conditions of water availability and disturbance. As a result, invasive ability appears to be controlled by a resource-based mechanistic process. *Schismus* appears to have the greatest invasive potential, as it positively responded to water and disturbance which are two factors that have been implicated in facilitating invasions by non-native species.

In contrast to *Schismus* spp. invasiveness patterns, *B. tournefortii* density was not influenced by water additions and soil disturbance. Mass germination of *B. tournefortii* has been correlated with precipitation patterns (Barrows et al. 2009). A plausible explanation for the lack of treatment response is seed dispersal limitations and as a result seed densities may have been low in the study plots.

B. tournefortii silique production was associated with soil disturbance. Plants in disturbed plots produced a higher number of siliques for their height relative to plants in control plots, suggesting that *B. tournefortii* under reduced competition may have partitioned available resources for silique production. An increased in seed production would translate into an increased probability of persistence and population expansion.

Native annual species responded positively to water additions and negatively to soil disturbance. It is well known that water availability stimulates germination of native desert plants (Beatley 1974), while disturbed habitats are not the most suitable for growth and establishment.

Conclusion

- Understanding factors that facilitate the dispersal and establishment of non-native species can help develop strategies to identify potentially invasive species, as well provide information on designing and implementing control techniques.
- The study supports a resource based community invasibility process for the establishment of *B. tournefortii* and *Schismus* spp. in the Mojave Desert.
- The three functional groups (invasive grass, invasive forb, and native annuals) benefited from increased resource availability, but differed in their response to manipulations highlighting the importance of invader identity and its associated functional attributes in successful community invasions.
- Monitoring for the arrival and expansion of new populations should focus on areas with high levels of soil moisture and disturbance
- Under future climate change models, it is difficult to predict patterns of invasibility, but an increase in water availability and disturbance regime should exacerbate non-native invasive species dominance in this arid ecosystem.

Literature cited

Barrows C W, Allen E B, Brooks W L, Allen M F (2009) Effects of an invasive plant on a desert sand dune landscape. Biol Invasions 11:673-686.

Beatley J C (1974) Phenological events and their environmental triggers in Mojave Desert ecosystems. Ecology 55:856-863.

Brooks M L et al. (2004) Effects of invasive alien plants on fire regimes. BioScience 54:677-688 .

D' Antonio C M, Vitousek P M (1992) Biological invasions by exotic grasses, the grass / fire cycle, and global change. Ann Rev Ecol Syst 23:63-87.

Davis M A, Grime J P, Thompson K (2000) Fluctuating resources in plant communities: a general theory of invasibility. J Ecol 88:528-534 .

Noy-Meir I (1973) Desert ecosystems: environment and producers. Ann Red Ecol Syst 4:25-51.

Patrick et al. (2007) Effects of an increase in summer precipitation on leaf, soil, and ecosystem fluxes of CO_2 and H_2O in a sotol grassland in Big Bend National Park, Texas. Oecologia 151:704-718.

Robertson T R, Zak J C, Tissue D T (2010) Precipitation magnitude and timing differentially affect species richness and plant density in the sotol grassland of the Chihuahuan Desert. Oecologia 162:185-197.

Vitousek P M, D' Antonio C M, Loope L L, Westbrooks R (1996) Biological invasions as global environmental change. Am Sci 84:468-478

Weltzin J F, Belote R T, Sanders N J (2003) Biological invaders in a greenhouse world: will elevated CO_2 fuel plant invasions. Front Ecol Environ 1:146-153.