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The presence of fennel affects the distribution of lizards on Santa Cruz Island

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THE PRESENCE OF FENNEL AFFECTS THE DISTRIBUTION OF LIZARDS ON SANTA CRUZ ISLAND

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ABSTRACT

THE PRESENCE OF FENNEL AFFECTS THE DISTRIBUTION OF LIZARDS ON SANTA CRUZ ISLAND

by Jennifer K. Gibson

Fennel (*Foeniculum vulgare*) is an invasive non-native herb that has become dominant in Santa Cruz Island's grassland communities. This study examined the effects of removing fennel on two lizard species, *Uta stansburiana* and *Elgaria multicarinata*. The data demonstrate that the impacts of fennel on lizard distribution and abundance are related to structural changes that favor one species *E. multicarinata* and selects against another *U. stansburiana*. The reduction of fennel through prescribed burning and the application of a relatively light concentration of Triclopyr (Garlon 3A) increased the abundance of *U. stansburiana* and reduced the abundance of *E. multicarinata*. These methods of reducing fennel are successful in that the treated fennel plots resembled grassland control plots in the distribution and abundance of lizards the year following treatment. This study is significant because rarely has there been a study on the impact of removing a non-native species from an ecosystem.

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Invasions by non-native plant and animal species are generally considered to be one of the greatest threats to biological diversity in natural areas (Soule 1990). Invasions and extinctions are common on islands and can be used to research the effects of inserting/deleting species or functional groups (D'Antonio and Dudley 1995). Non-native species have the ability to adapt to their surroundings, rapidly expand their range, and alter or dominate island communities. This often results in the displacement of native species, alteration of community structure and a change in nutrient cycling (Vitousek et al. 1995).

The California Channel Islands hold a striking example of the detrimental effects of non-native species on an ecosystem. The most severe effects have been due to exotic animals, especially cattle, feral sheep, goats, and pigs (Brumbaugh 1980). Furthermore, many species of non-native plants have become established and dominate most of the island's plant communities. Non-native plants now comprise 20-48% of the species on the islands, and 25-80% of the ground cover (Halvorson 1992; Klinger, unpubl. data).

Santa Cruz Island, the largest and most biologically diverse of the Channel Islands, is managed as an ecological preserve by The Nature Conservancy and Channel Islands National Park. One of the most important issues for both organizations is the expansion of fennel (Foeniculum vulgare), a perennial herb from the Mediterranean region. Fennel was established on Santa Cruz Island at least one-hundred years ago (Greene 1887). Since 1991, the distribution and abundance of fennel has increased, predominantly in what were previously grasslands (Beatty and Licari 1992). Several factors influenced this expansion (Brenton and Klinger 1994), to where it is estimated that fennel now occurs on almost 11% of the island. In over 75% of the areas containing fennel, it forms dense stands that often reach heights of three meters, and comprise as much as 90% of the vegetation cover (Klinger, unpubl. data). In areas where fennel dominates, few native plants exist (Beatty and Licari 1992; Brenton and Klinger 1994) due to this species' sheer physical exclusion, shading, and allelopathic effects (Dash and Gliessman 1994). Because of its impact on native plant species and unyielding expansion, The Nature Conservancy on Santa Cruz Island has made it a management priority to reduce the cover of fennel on the preserve by 75-85%. In a series of experiments beginning in 1991, Brenton and Klinger (1994) developed a management protocol for reducing fennel cover in grasslands. This protocol consists of burning areas with fennel in the Fall, followed by spraying the regrowth with a relatively light concentration of Triclopyr (Garlon 3A) the following two Springs. The result of these trials indicate that while the percent cover of fennel can be reduced 75-100% in grassland areas accompanied by a small yet significant increase in native herbaceous species, the areas are still dominated by other non-native herbaceous plants (Brenton and Klinger, unpubl. data).

Non-native species threaten ecosystems and the need for their control in natural areas is rarely disputed by conservation scientists and land managers (Temple 1990). However, there is little or no data indicating that controlling a non-native species will result in the recovery of an ecological system and yet this must be a critical step for reducing threats to native biota. It is essential to know whether removing or significantly reducing the abundance of a non-native plant species will lead to the re-establishment of native plant and animal species, or whether it will result in a community still dominated by other non-natives. This aspect of land management is particularly important because the eradication or control of non-native species is a manipulation of disturbance and successional patterns in an ecosystem, and it is these changes that may create conditions favorable to other non-native species, such as the removal of domestic livestock created conditions favorable to non-native herbaceous species (Brenton and Klinger 1994; Klinger et al. 1994; Laughrin et al. 1994). Therefore, it is important to understand how communities change following such manipulation, whether the population densities of species in the system return to levels present prior to the perturbation, and if the species composition is similar to the community prior to the invasions.

This study is a part of The Nature Conservancy's Adaptive Management Program, a four year cooperative project whose goal it is to determine the effects of removing fennel on the vegetation, invertebrates, herpetofauna, and soils of Santa Cruz Island. The objective of this study is to document how the removal of fennel affects the distribution and abundance of two lizard species, Elgaria multicarinata (Southern Alligator Lizard) and Uta stansburiana (Side-blotched Lizard), on Santa Cruz Island. Lizards have been chosen as the focal taxa for three reasons: 1) little is known of the distributions and ecology of herpetofauna on the Northern Channel Islands; 2) lizards represent an intermediate to top predator with a small home range compared to other predators (e.g., birds) and; 3) they have specific microhabitat requirements and can reflect changes in the vegetation structure of a community (Fitch 1955; Pianka 1966; Jones 1981; Fox 1983), and their prey base as well. Thus, this paper evaluates the success of removing fennel based on what its impact is on the herpetofauna, not simply whether fennel is reduced or eliminated.

MATERIALS AND METHODS

This study was conducted in the eastern section of the Central Valley of Santa Cruz Island. The Central Valley lies between two north and south ridges that run in an east-west direction for 12.5 miles (20 km). The eastern section of the Central Valley is dominated by extensive stands of fennel in which there still exists some patches of grasslands that are relatively free of fennel.

Three species of lizards and two species of salamanders occur on Santa Cruz Island. A pilot study conducted in May-August 1997 determined that U. stansburiana and E. multicarinata inhabit the grasslands and fennel stands of the Central Valley. The Western Fence Lizard (Sceloporis occidentalis becki) was rarely found in grassland and fennel plots. The Pacific Salamander (Batrachoseps pacificus pacificus) and the Black-bellied Salamander (Batrachoseps nigriventris) were sampled during the late winter and early springs of 1997 and 1998. The latter three species were omitted from the study because of a low number of observations.

U. stansburiana is a territorial, insectivorous, sit-and-wait foraging lizard (Tinkle 1967; Wilson 1991). Past research has found that this species is essentially annual, with few surviving to breed for more than one year. Adults have small home ranges (Spoeker 1967; Tinkle 1967; Wilson 1991) and females can have up to four clutches per summer.

Alligator lizards appear to be diurnal, insectivorous lizards that prefer relatively cool and humid environments. The secretive nature and poor recapture success of members of this family makes it difficult to study. These lizards appear to be mostly sit-and-wait predators (Vitt and Price 1982; Kingsbury 1991) with some evidence that E. multicarinata occasionally exhibits slow-search foraging. Individuals of this species are apparently active March through early May (Kingsbury 1995).

Six treatments, two control and four variations of fennel removal (Table 1) were used to evaluate changes in the abundance of U. stansburiana and E. multicarinata relative to fennel removal; sites were monitored before and after fennel removal to assess change. The Nature Conservancy used a combination of prescribed burning and herbicide (Triclopyr-Garlon 3A) application in an effort to reduce fennel cover to 95-100% in the treatment conditions. The Grassland Burned and Sprayed, Fennel Burned and Sprayed, and Fennel Burned, Sprayed and Seeded treatments were burned during the Fall of 1997. The Grassland Burned and Sprayed, Fennel Sprayed, Fennel Burned and Sprayed, and Fennel Burned, Sprayed and Seeded treatments were sprayed with an herbicide (6.0% solution of Triclopyr-Garlon 3A) during the Spring of 1998. The Fennel Burned, Sprayed and Seeded treatment was sowed with seeds of native herbaceous species during the first winter following the initial application of herbicide. There is not a Grassland Burned, Sprayed, and Seeded treatment because grasslands were the source of seeds. In the initial design, only five treatments were included, and each was replicated in five randomly located macroplots (0.1 hectares each). The Fennel Sprayed treatment was included unintentionally; one of the five Fennel Burned and Sprayed plots was not burned because a spot fire deferred the time and manpower it would take to complete the entire burn unit. For all statistical analyses in this experiment, alpha was set at 0.025 to avoid a Type I statistical error.

Relative lizard abundance was estimated by using a mark-recapture sampling technique in a three-by-three pitfall trap grid. Lizards were sampled before (May-August 1997) and after burn, spray, and seeded treatments (June-October 1998). Traps were checked every 4-5 days, and more frequently during warmer months. Individual lizards were marked by "toe-clipping", which involves cutting at least one toe from one foot. Data recorded on individual lizards includes species, weight, length from snout to vent, length from vent to the tip of the tail, sex, age class, and physical condition.

A Two-way Analyses of Variance (Tabachnick and Fidell 1996) was used to determine whether changes in lizard abundance over time differed among treatments; in this case there would be a significant interaction between time and treatment. The number of U. stansburiana and E. multicarinata were averaged within each macroplot for analysis; a preliminary analysis indicated that levels of subsamples (traps) were sufficient to allow pooling. Originally, the data were to be analyzed with a repeated measures design because collections were made over time. However, the number of individuals caught per unit time was too few to analyze so the number of individuals caught was pooled over time.

To examine potential patterns in the relative abundance of the two lizard species at the microhabitat (trap) level, all trap sites were characterized through a Principal Components Analysis (PCA) of lizard abundance for the two species (Tabachnick and Fidell 1996). A two-tailed t-test (Zar 1996) was used to determine the difference in the mean factor scores for plots that were in the fennel (FBS+FBSS+FC+FS) compared to plots that were in grassland habitats (GBS+GC) before treatment. A One-way Analysis of Variance (Zar 1996) was used to test for differences in the mean factor scores between treatment conditions after the plots had been burned, sprayed, and seeded. The a priori (Zar 1996) comparisons for this ANOVA tested for differences between all fennel plots (FBS+FBSS+FC+FS) and all grassland plots (GBS+GC); the effect of burning, spraying, and seeding on fennel plots (FBS+FBSS+FS) compared to fennel control plots (FC); the effect of burning and spraying on the fennel (FBS + FBSS) to the fennel plot that was just sprayed (FS); the effect of seeding in comparing fennel burned and sprayed plots (FBS) against fennel burned, sprayed, and seeded plots (FBSS); and the effect of burning and spraying on grassland plots (GBS) compared to grassland control plots (GC). It is important to specify that these Principal Components Analyses were used to detect patterns and not test actual hypotheses among treatments. Therefore the results should be interpreted only as suggesting trends for future studies.

In the summer of 1998, the percent cover of fennel, grass, herbaceous species, litter, bare ground, pig rooting, and holes wider than two centimeters were estimated using Daubenmire values (Daubenmire 1959) in one square meter quadrats. Height, canopy, and thatch depth were also recorded for fennel, grass, and herbaceous species. Square meter quadrats were randomly selected along three thirty-meter tapes, which were randomly selected on north, south, east, or west sides of each plot. A Canonical Correlation (Tabachnick and Fidell 1996) was used to test the relationship between the abundance of lizards and habitat characteristics in each plot. Prior to the Canonical Correlation Analysis, Pearson's Correlation Coefficients were computed for all possible pairs of habitat variables to determine which variables were interrelated. If two variables were highly correlated ($r > 0.600$), one of the pair was excluded from further analysis.

Variables retained for analysis were: the number of E. multicarinata, the number of U. stansburiana, the percent cover of fennel, the grass thatch depth, and herbaceous species height.

RESULTS

Two-way Analyses of Variance showed no evidence of a significant interaction in the mean number of U. stansburiana or E. multicarinata among treatments (Fennel Burned and Sprayed; Fennel Burned, Sprayed, and Seeded; Fennel Sprayed; Grassland Burned and Sprayed; Fennel Control; Grassland Control) and year (before and after treatment). However, the Minimum Detectable Difference (MDD) (Zar 1996) for U. stansburiana at 95% power was 0.0554, and was only capable of resolving differences as large as 84.9% of the Grand Mean (0.066). For E. multicarinata, the MDD at 95% power was 0.020, and could only resolve differences greater than 90% of the Grand Mean (0.032). Therefore, it is likely that the null hypothesis for the interaction was accepted because of an inadequate sample size (number of macroplots per treatment). The effect of year (before and after treatment) indicated that there was no significant difference ($P = 0.056$) in the number of E. multicarinata trapped before and after treatment (Table 2). The average number of U. stansburiana trapped before treatment (0.051) was significantly greater ($P = 0.009$) than the average number trapped after treatment (0.033) (Table 3). Yet for both species, the effect of treatment was significant, and when the grassland and fennel treatments were tested independently, no significant difference in the number of U. stansburiana or E. multicarinata was found. This suggests that these lizard species may have microhabitat preferences specific to the plot level.

The two-tailed t-test on the Principal Component Analysis scores characterizing lizard abundance computed prior to treatment demonstrated that the abundance of the two lizard species differed between the grassland plots and the fennel plots (Figure 1). The mean Factor 1 scores for the fennel plots (-0.42) were significantly ($P<0.001$) less than in the grasslands (0.36). The high Factor 1 scores for grasslands indicated a high abundance of U. stansburiana and a low abundance of E. multicarinata, whereas the fennel plots were characterized by a high abundance of E. multicarinata, and a low abundance of U. stansburiana.

The first two a priori comparisons from the ANOVA on the Principal Components Analysis scores characterizing lizard abundance after treatment showed that fennel controls (untreated) and the treated fennel sites were more like the original grassland sites (Table 4, Figure 2). As with the PCA analysis conducted on sites before treatment, High Factor 1 scores characterize sites with a high number of U. stansburiana, and a low abundance of E. multicarinata, whereas low Factor 1 scores characterize sites with a low abundance of U. stansburiana, and a high abundance of E. multicarinata. The first a priori comparison demonstrated that the mean Factor 1 scores of all fennel plots were significantly ($P<0.001$) lower than the grassland plots. As with the results computed prior to treatment, the fennel plots were characterized by a high abundance of E. multicarinata and a low abundance of U. stansburiana, whereas the grassland plots exhibited the reverse. The second a priori comparison indicated that fennel control plots had significantly ($P<0.001$) greater mean Factor 1 scores than fennel treated plots, demonstrating that the fennel treated plots have a lower abundance of E. multicarinata but greater abundance of

U. stansburiana than the fennel control plots. Therefore, the fennel treated plots were similar to the original grassland plots.

The remaining three a priori comparisons indicated that the type of fennel treatment did not seem to have an effect on abundance of the two lizard species. The third a priori comparison indicated that there was no significant difference ($P=0.300$) in the mean Factor 1 scores between the fennel plots that were burned and sprayed compared to the fennel plot that was sprayed only. The fourth a priori comparison indicated that there was no significant difference ($P=0.490$) between the fennel plots that were burned and sprayed and the fennel plots that were burned, sprayed, and seeded with native herbaceous species. The final a priori comparison found no significant difference ($P=0.210$) in the number of lizards in the grassland control and grassland treatment conditions.

The Canonical Correlation demonstrated that plots with a large abundance were characterized by a high percent cover of fennel and grass thatch depth (Figure 3). Root 1 was significant ($P<0.001$) with a correlation of 0.619 between lizard abundance and habitat characteristics (Table 5). Conversely, plots with a high abundance of U. stansburiana were characterized by a low percent cover of fennel and little grass thatch depth, but the average height of the herbaceous species (such as Hemizonia fasciculata, Centaurea melitensis, Brassica nigra) was high.

DISCUSSION

This study suggests that the distributions and abundance of U. stansburiana and E. multicarinata are affected by the presence of fennel on Santa Cruz Island. The reduction of fennel through prescribed burning and the application of an herbicide appeared to increase the abundance of U. stansburiana while at the same time reduced the abundance of E. multicarinata. The fennel control and grassland plots showed no difference in lizard abundance before and after treatment. This suggests that both species have specific microhabitat requirements that are related to changes in the structural composition of the vegetation community. This hypothesis is consistent with Pianka (1966), who documented the importance of the structural composition of a vegetation community with the abundance and diversity of lizard species. Jones (1981) also found that grazing affected overall lizard abundance and species diversity when associated with changes in the vegetative structure of a given community. Communities not affected structurally by grazing showed little or no difference in lizard abundance or diversity.

The effects of fennel on the distribution and abundance of U. stansburiana and E. multicarinata may be due to a difference in foraging style between the two species. Pianka (1966) hypothesized that certain lizards prefer various physical structures while foraging. In doing so, he grouped lizards into foraging styles based on preference for particular physical structures: widely foraging species; sit-and-wait species who forage while sitting on rocks, trees, and downed tree limbs; sit-and-wait species who forage in open spaces between shrubs; herbivorous species; and nocturnal species. U. stansburiana is a "sit-and-wait" predator that waits under vegetation and exploits open spaces, usually ambushing when a food item basically presents itself (Pianka 1966). However, it is believed that E. multicarinata may be intermediate in foraging strategy, becoming more active and utilizing "slow-search" foraging at higher temperatures, but ambushing at lower temperatures (Kingsbury pers. com.). The high abundance of E. multicarinata in dense stands of fennel suggests that this species either actively searches for prey, or that it would fall into a new category of foraging, preferring to ambush prey in a microenvironment that consists of significant amounts of grass thatch and dense cover.

However, the preference that E. multicarinata has for fennel may be related to the micorenvironment that this invasive plant creates. The dense fennel stands are humid, moist, and have cooler temperatures than the grasslands. E. multicarinata has a selected body temperature of 5-8 C° below many other species of lizards, and the principal activity season for this species is the cooler months of March through early May (Kingsbury 1995). With continued activity during overcast weather, the more mesic microenvironment created by the fennel may be the optimum habitat for E. multicarinata. The xeric microenvironmental conditions at or near the surface in the grassland communities may make for an unfavorable microenvironment for a species that optimally operates at a lower field body temperature. If in fact these individuals do occasionally actively forage for prey over large areas, it may be that U. stansburiana is favored in the grassland and fennel treated plots because individuals can exist in a xeric environment by remaining relatively motionless until ambushing prey. This coincides with the findings of Fitch (1955), who discussed the relationships between habitat structure and populations of Eumeces obsoletus. He found that the abundance of this species was greatest where there was a high composition of perennial grasses, which tend to moderate conditions of surface and near-the-surface microenvironmental regimes (increase water retention and cooler temperatures). He concluded that the mesic microenvironment created by perennial grasses allowed E. obsoletus to maintain deep body temperatures within a preferred range while actively foraging. Pianka and Parker (1972) also found that the active foraging behavior of Callisaurus draconoides requires brushy, low-height shrubs for maintenance of deep body temperatures. Jones (1981) found a lower abundance of active foraging species where there was the greatest effect from heavy livestock gazing. He related this to losses in low height vegetation cover, particularly perennial grasses.

Differences in prey base may also account for changes in the distribution and abundance E. multicarinata and U. stansburiana. Past research has shown that changes in invertebrate fauna can effect lizard abundance. Vitt and Ohmart (1974) discussed changes in invertebrate fauna and reduced population numbers of Cnemidophorus tigris, hypothesizing that losses in perennial grass reduced the abundance of certain invertebrate species and thus reduced food available to C. tigris. The invertebrate data from this project is currently in the process of being identified and analyzed but, from personal observation, the invertebrate species that inhabit the dense fennel stands differ dramatically from the grassland plots. To link the changes observed in lizard abundance to changes in invertebrate diet, stomach contents should be examined. Because of a low number of observations and low recapture success in plots, this was not done in the field seasons of 1997 and 1998.

The inadequate sample size (number of macroplots per treatment) became a design constraint. The inability to detect differences as large as 84.9%, and greater than 90%, of the grand mean for U. stansburiana and E. multicarinata respectively, suggests that a large number of macroplots need to be added to account for this poor sampling power. However, the addition of macroplots may be more labor intensive and time consuming than necessary. A suggested experimental design for future studies is to use a randomized block design which would increase the power of the main hypothesis and eliminate some of the variation that exists between plots.

Data presented in this paper demonstrate that the impacts of fennel on lizard distribution and abundance are related to structural changes that favor one species (E. multicarinata) and selects against another (U. stansburiana). It is obvious that there should be further research to determine exactly how these structural changes effect the two lizard species. Although small, this study is a step in arriving at a full and integrated understanding of the many levels of associations island herpetofauna have with an invasive non-native plant. From a land management perspective, the grassland control plots in this study are the criterion of success in eliminating/reducing fennel from sites that were historically grasslands before invasion. Thus, the data collected in this study indicate that the methods of removing fennel on Santa Cruz Island are successful based on the distribution and abundance of U. stansburiana and E. multicarinata the year following treatment.

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Table 1. The habitat/treatment conditions and number of replicates.

Treatment	Designation	N	Abbreviation
Fennel Burned and Sprayed	Treatment	4	FBS
Fennel Burned, Sprayed and Seeded	Treatment	5	FBSS
Fennel Sprayed	Treatment	1	FS
Grassland Burned and Sprayed	Treatment	5	GBS
Fennel Control	Control	5	FC
Grassland Control	Control	5	GC

Table 2. Two-way Analysis of Variance for E. multicarinata.

Source	Sum-of-Squares	df	Mean-Square	F-Ratio	P
Year	0.003	1	0.003	3.882	0.056
Treatment	0.012	4	0.003	3.661	0.012
Fennel Plots	0.008	1	0.004	3.408	0.050
Grassland Plots	0.001	1	<0.001	2.238	0.154
Year*Treatment	0.002	4	<0.001	0.662	0.650
ERROR	0.032	40	0.001		

Table 3. Two-way Analysis of Variance for U. stansburiana.

Source	Sum-of-Squares	df	Mean-Square	F-Ratio	P
Year	0.020	1	0.020	7.495	0.009
Treatment	0.050	4	0.013	4.794	0.003
Fennel Plots	0.003	1	0.002	0.641	0.535
Grassland Plots	0.002	1	0.002	0.582	0.457
Year*Treatment	0.013	4	0.003	1.225	0.316
ERROR	0.104	40	0.003		

Table 4. One-way Analysis of Variance with a priori comparisons of differences among treatments in Factor 1 PCA scores of relative abundance of the two lizard species after treatment.

Source	Sum-of-Squares	df	Mean-Square	F-Ratio	P
Treatment	29.25	5	5.85	7.10	<0.001
FBS+FBSS+FC+FS vs GBS+GC	9.44	1	9.44	11.46	<0.001
FBS+FBSS+FS vs FC	13.79	1	13.79	16.73	<0.001
FBS+FBSS vs FS	0.91	1	0.91	1.10	0.300
FBS vs FBSS	0.41	1	0.41	0.49	0.490
GBS vs GC	1.32	1	1.32	1.60	0.210
ERROR	113.75	138	0.82		

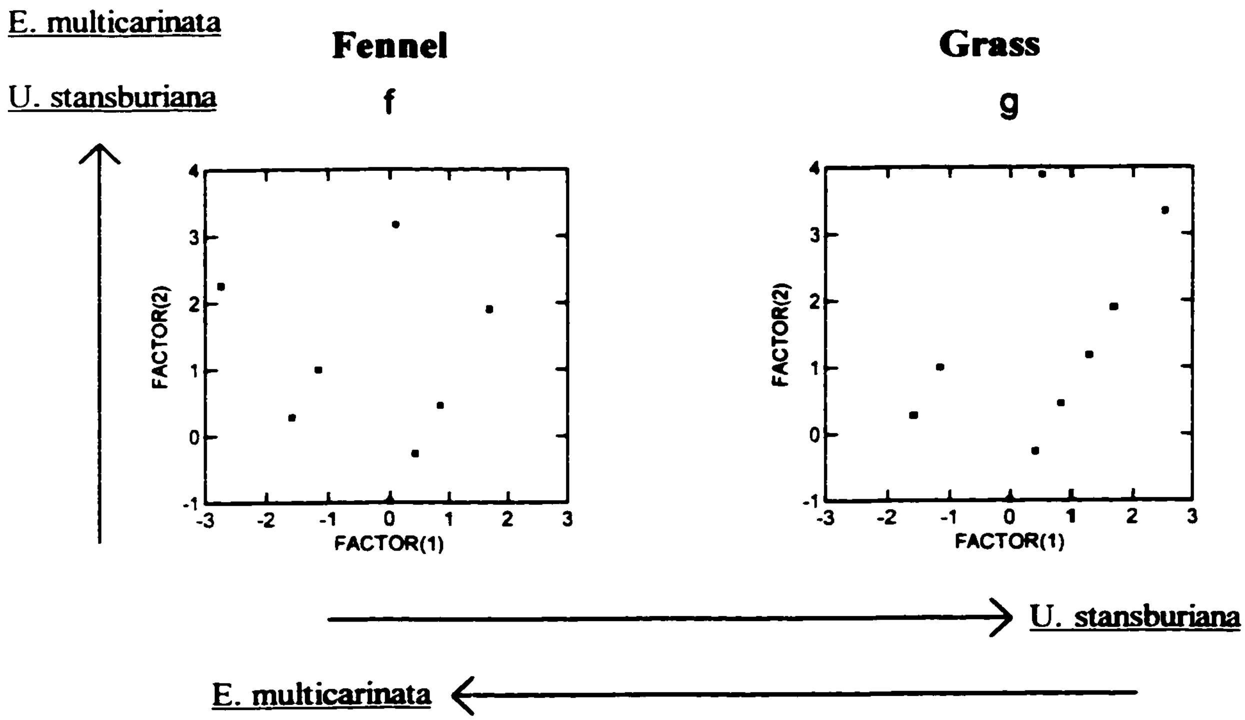
Table 5. Summary of loadings for Canonical Root Pair 1.

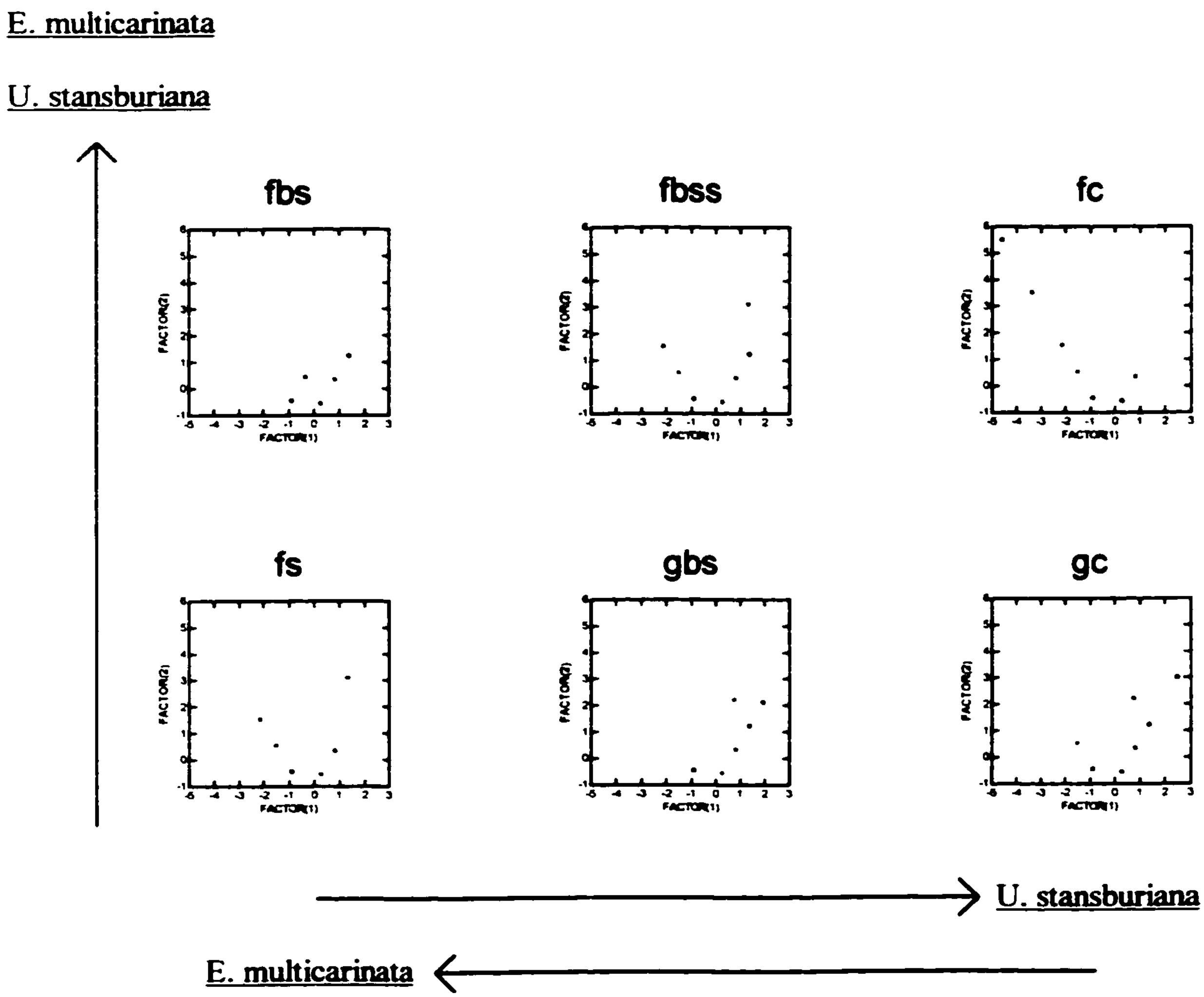
Lizard Variables	Canonical Pair 1	Habitat Variables	Canonical Pair 1
U. stansburiana	-0.560	Percent Cover Fennel	0.801
E. multicarinata	0.944	Grass Thatch Depth	0.415
		Herbaceous Species Height	-0.401

Figure 1. Factor 1 vs. Factor 2 for U. stansburiana and E. multicarinata in fennel (f) and grassland (g) plots sampled prior to treatment.

Figure 2. Factor 1 vs. Factor 2 for U. stansburiana and E. multicarinata sampled in the following treatments: fennel burned and sprayed (fbs); fennel burned, sprayed, and seeded (fbss); fennel sprayed (fs); fennel control (fc); grassland burned and sprayed (gbs); and grassland control (gc).

Figure 3. Canonical Correlation Analysis of the relationship between the abundance of U. stansburiana and E. multicarinata with such microhabitat variables as the percent cover of fennel, grass thatch depth, and the height of herbaceous plant species.


E. multicarinata
U. stansburiana
Fennel
f
Grass
g
FACTOR(2)
FACTOR(1)
U. stansburiana
E. multicarinata


E. multicarinata
U. stansburiana
fbs
fbss
fc
fs
gbs
gc
FACTOR(2)
FACTOR(1)
U. stansburiana
E. multicarinata

Canonical Correlation = 0.619   p<0.001