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VERNAL POOL ENHANCEMENT

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SUMMARY

The purpose of this study was to investigate ways to enhance the quality of vernal pools which have been damaged by vehicles or invaded by exotic species. A weed removal experiment and road pool enhancement experiment were carried out during the 1987/1988 growing season. In the weed removal experiment *Polypogon monspeliensis* plants were removed from half of 18 transects established prior to the winter rains of 1987. In the spring of 1988 all transects were sampled to estimate cover of *Polypogon* and the endangered pool species, *Pogogyne abramsii*. The road pool enhancement experiment was a two-factor experiment with seeding (added or not added) and pool recontouring and decompaction (dug or not) as the factors. Treatments were applied to eight pools in the fall of 1987. During the winter, water depth in pools was monitored at regular intervals. In the spring of 1988 transects were sampled for the presence of all vascular plant species.

Pogogyne occurred in significantly more quadrats in weeded transects compared to unweeded ones. In road pools contouring and seeding did not affect the number of species per pool, the number of pool species present, or the frequency of three common pool species (*Downingia cuspidata*, *Eryngium aristulatum* var. *parishii*, and *Psilocarphus brevissimus*). Frequency of *Pogogyne* was significantly greater in recontoured and seeded pools, and the interaction of the two treatments was also significant.

These results indicate that hand weeding of *Polypogon monspeliensis* may be a useful management tool to enhance populations of *Pogogyne abramsii*. Hand seeding of *Pogogyne* can

successfully reintroduce this species to pools where it has been extirpated by vehicle damage. Decompaction and recontouring of pool soils increased the probability of successful establishment of *Pogogyne*. However, this one-year study did not establish whether or not *Pogogyne* or other pool species can maintain themselves over a period of years where they have been seeded into pools with decompacted and recontoured soils.

INTRODUCTION

While construction is the primary threat to San Diego County's remaining vernal pools, damage by vehicles and invasion by exotic plant species have had a significant impact (Bauder 1986, 1987a). Vehicles not only crush plants, but their tires remove soil and compact what remains. After years of such abuse, these pool basins are often nearly devoid of native vernal pool species. In addition, they generally hold water much longer than less disturbed pools. Most pool species are tolerant of inundation for periods up to 4 mo, but when water stands for much longer, their mortality increases (Bauder 1987b). They are not associated with permanent bodies of water (Holland and Jain 1977, Zedler 1987a).

On the coastal terraces, where the majority of San Diego County's pools occur, herbaceous vegetation is dominated by exotics. Most of these species cannot tolerate long periods of inundation so that they are eliminated from vernal pool basins in years of average or greater precipitation (Bauder 1987b). A number of exotic species appear to tolerate conditions comparable to those of vernal pools--winter/spring inundation followed by a long summer drought. These species are *Agrostis avenacea*, *Cotula coronopifolia*, and *Polypogon monspeliensis*.

The purpose of this study was to investigate ways to enhance the quality of pools which have been damaged by vehicles or invaded by exotic species. A weed removal experiment and road pool enhancement experiment were carried out during the 1987/1988 growing season. In the weed removal experiment transects were established in five vernal pools. Seeding *Polypogon monspeliensis* plants were removed from half of the transects prior to the winter rains. In the spring of 1988 all transects were sampled to estimate cover of *Polypogon* and the endangered pool species, *Pogogyne abramsii*. The road pool enhancement experiment was a two-factor experiment with seeding (added or not added) and pool recontouring and decompaction (dug or not) as the factors. Treatments were applied to eight pools in the fall of 1987 after the first rains but prior to the main rainy season. During the winter, water depth in pools was monitored at regular intervals. In the spring of 1988 transects were sampled for the presence of all vascular plant species.

METHODS

The project was carried out on the Miramar Mounds National Natural Landmark, San Diego County, California. The site is on San Diego's coastal terrace, and the terrain is characterized by "Mima mound" topography (Cox 1984). In depressions between the mounds vernal pools develop after the rainy season begins in late fall. The site is moderately disturbed. Until the 1950's it was grazed and occasionally brushed. Since that time it has provided flyover space for Navy aircraft, and disturbance has been primarily from illegal trespass by off-road vehicles

In September, 1988 the "Landmark" was surveyed for possible sites for both portions of the project: the enhancement of vehicle-damaged vernal pools and the removal from pools of the exotic, *Polypogon monspeliensis* . In September, 1987 all road depressions were marked with surveyor's flagging so that they could be monitored once fall rains began. Beginning October 12, 1987 many of the road depressions began to hold water as the result of rainfall, and the maximum water depth for each depression was estimated on October 12, 14, 17, and 29. Eight pools were chosen for the enhancement study. Five pools with heavy infestations of *Polypogon* were selected for the weeding experiment.

Weed removal experiment

At the edges of the five pools wooden stakes were placed every other meter, beginning at 1 m (Fig. 1). Matching stakes were placed on the opposite side of the pools. Large nails were embedded 0.5 m to each side of the wooden stakes on both sides of the pools. Strings were attached to the nails so that a 1-m wide transect was defined, with its midline extending from the wooden stake on one side of the pool to the one on the opposite side. Between October 15 and October 28, 1987, every other transect was hand-weeded of the previous year's crop of *Polypogon* , including seed heads. Plant material was placed in plastic bags and removed from the site. A

Figure 1. Layout for weed removal transects.

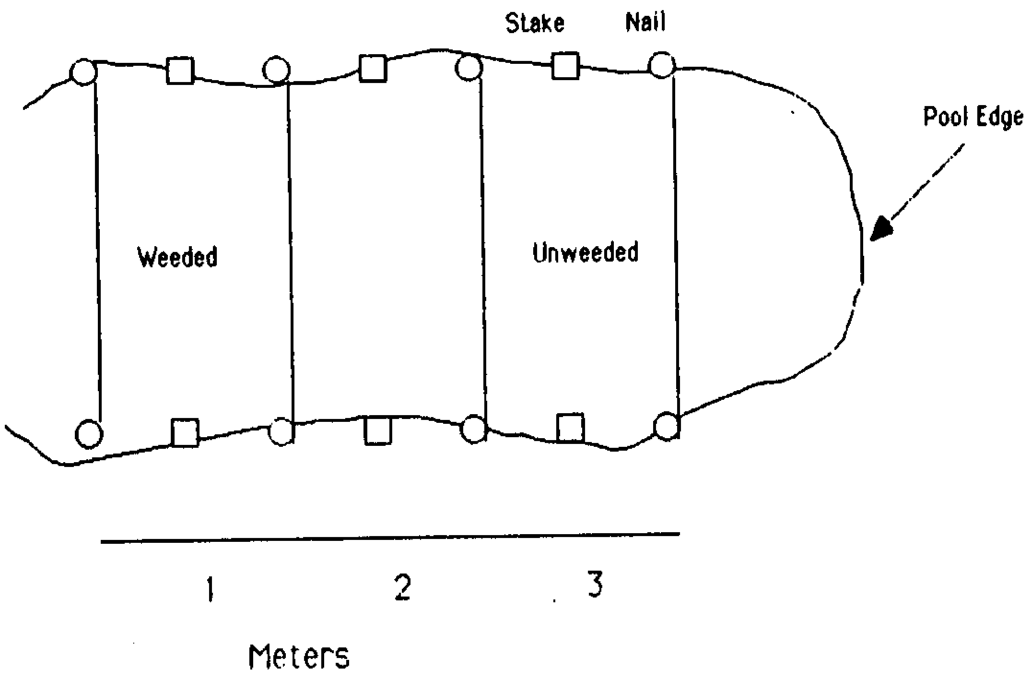
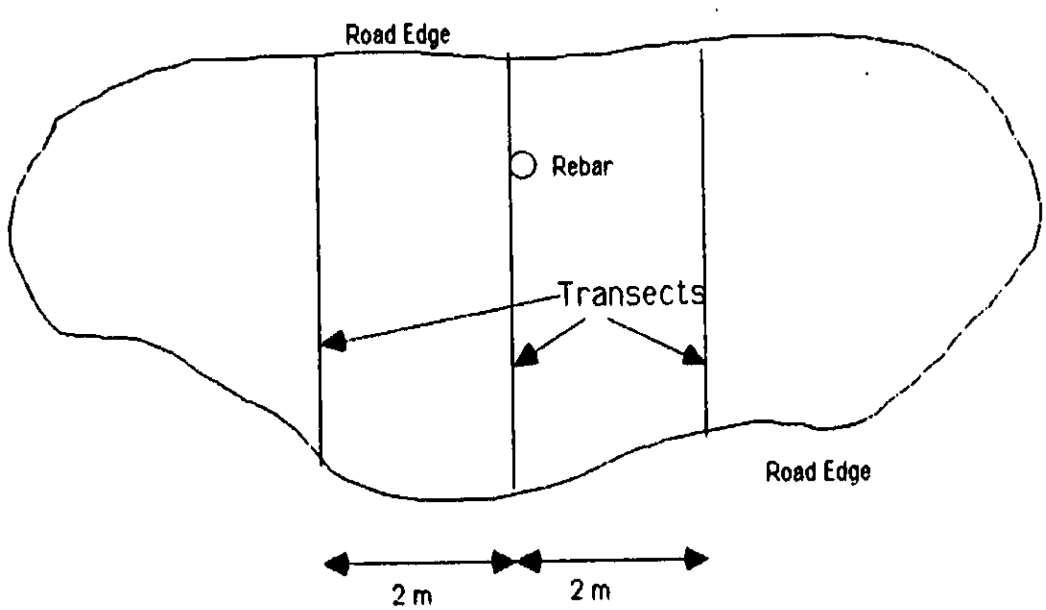


Figure 2. Transects for road pool vegetation sampling.



total of nine transects were weeded, and an equal number were not weeded.

Vegetation sampling was done in May, 1988. A meter tape was laid out along the midline of the transects. A square sampling frame 1 dm on a side was moved along the transects and presence or absence of *Polypogon* and *Pogogyne abramsii* were recorded in each quadrat. Weeded transects had 738 quadrats, and unweeded transects had 664 quadrats.

Road pool enhancement experiment

A two-factor experiment was designed to estimate the relative importance of seeding and decompaction of surface soil to the water holding characteristics, species diversity, and plant cover of pools repeatedly damaged by vehicles. Pools were randomly assigned to one of the four possible treatment combinations: 1) no digging-no seeding, 2) no digging-seeding, 3) digging-no seeding, and 4) digging-seeding. This resulted in two pools per treatment combination.

Prior to any digging or seeding pools were surveyed for pool species which had already germinated. After digging, pool areas were estimated so that equivalent amounts of seed material could be spread on equivalent areas.

All pools had some standing water at the time digging was begun on November 2, 1987. It was necessary to wait until the soil was moist to decompact the surface soil because the dried clayey soils were cement-like and impossible to work. Unfortunately, when soils of this type are wet they become very plastic, and it is difficult to avoid the creation of large clods. All pools which were assigned to the digging treatment were spaded approximately 2-3 dm deep. Deep ruts were smoothed out, and soils pushed to the side of the pools by vehicle tires were replaced into the pools. After the initial digging, soil surfaces were reworked to break up drying clods and to smooth contours. When digging was complete, a 1 m piece of metal rebar was pounded into the ground at what was was believed to be the lowest point of each pool. Rulers were attached to each rebar so that water depths could be estimated without entering the pool.

Pools in the seeding treatment received seeds on November 16, 1987. Seeds had been collected the previous fall from nearby pools (c. 200-500 m) which were destroyed by freeway construction the winter of 1986/87. Seed collection methods were as described by Zedler (1987b). Seed material was spread out on large drop cloths, homogenized, then replaced in large plastic trash bags. An equivalent amount of seed material per unit area was broadcast on each pool designated as a seed-added pool.

Water levels were monitored beginning December 5, 1987. Pool depths at the rebars were measured within 24 hr of each rainstorm and every 3 days thereafter until the pool had no standing water.

Point-frame sampling of vegetation transects was begun on March 21, 1988 when all pools had drained and dried and sampling was completed a month later. Three transects were established in each pool: one extending from road edge to road edge and passing through the pool center close to the rebar, and two other parallel transects 2 m to each side of the central transect (Fig. 2). A 30 by 15 cm point frame with 11 rows of five points was laid next to a tape placed along the transect line, and the species present at each of the 55 points were recorded. Species not at a point but also present within the quadrat were recorded. The frame was moved along the transect until all 30 cm-intervals were sampled.

Data analysis

Three of the five "Weed removal" pools had so few plants of either *Polypogon* or *Pogogyne*, that they have not been included in the analysis. All analysis has been done on two pools with a total of 556 weeded quadrats and 486 unweeded quadrats. Statistical tests using proportions have been performed on arcsine transformed data.

Number of species per road pool was estimated from transect data.

RESULTS

Weed Removal Experiment

The proportion of the total number of quadrats with *Pogogyne abramsii* present was significantly greater in weeded transects compared to unweeded ones (*t*-test: $t = 3.275$ df= 11; p= 0.0084), but the proportion of quadrats with *Polypogon monspeliensis* did not differ between treatments (*t*-test: $t = 0.977$; df= 11; p= 0.3515)(Fig. 3). Quadrats can be further subdivided into four categories: A) only *Pogogyne* present, B) only *Polypogon* present, C) Neither *Polypogon* nor *Pogogyne* present, or D) both *Pogogyne* and *Polypogon* present. In weeded transects compared to unweeded ones, a greater proportion of the quadrats has *Pogogyne* without

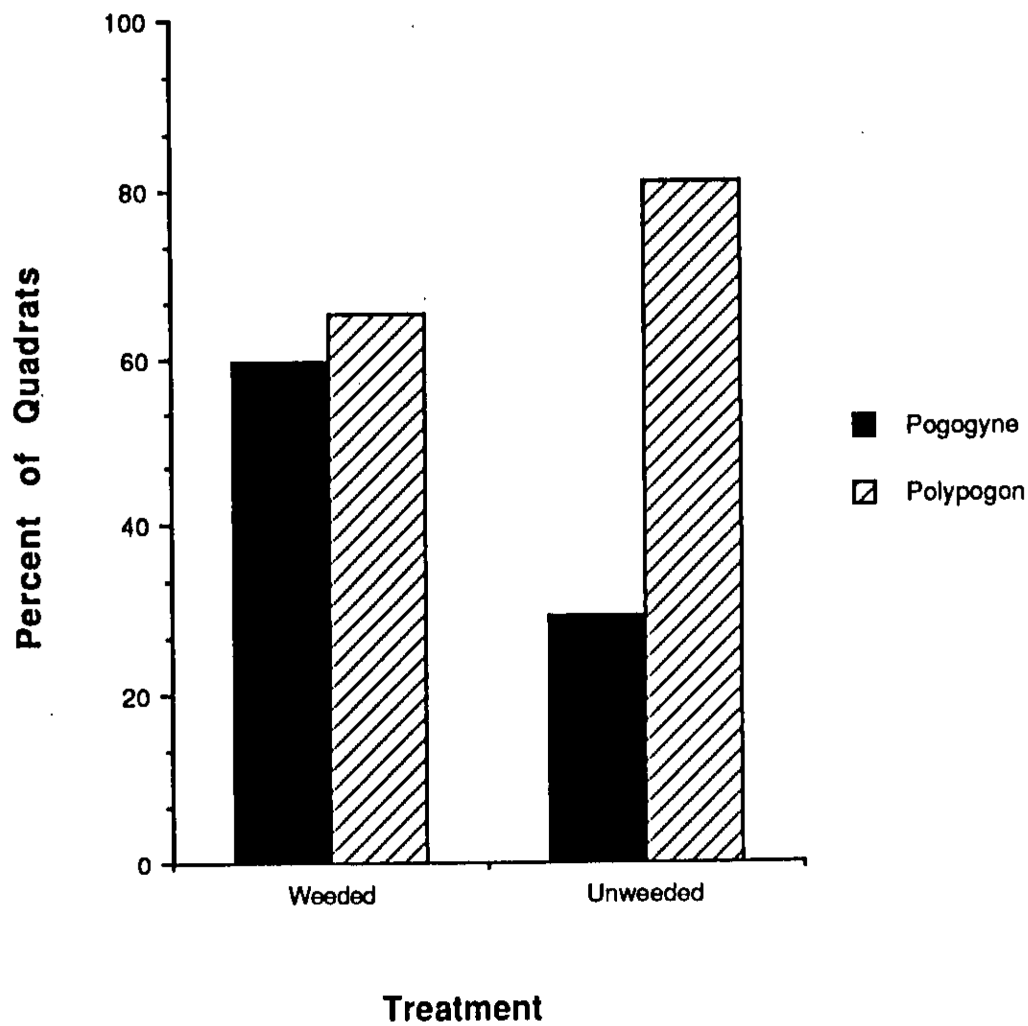


Figure 3. Percent of quadrats with *Polypogon monspeliensis* or *Pogogyne abramsii* in weeded and unweeded transects.

Polypogon, and in unweeded transects a greater proportion has *Polypogon* without *Pogogyne* (Table 1).

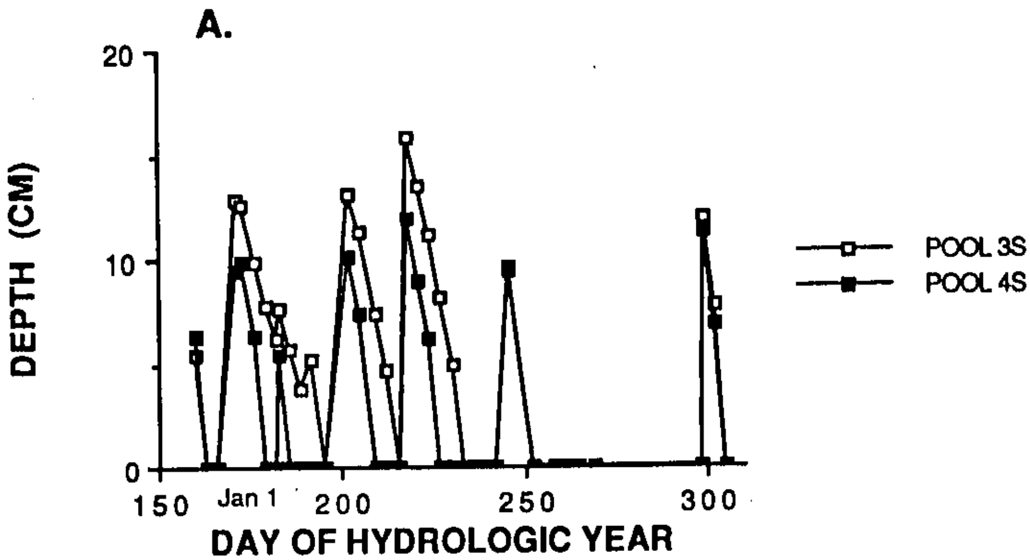
Road Pool Enhancement Experiment

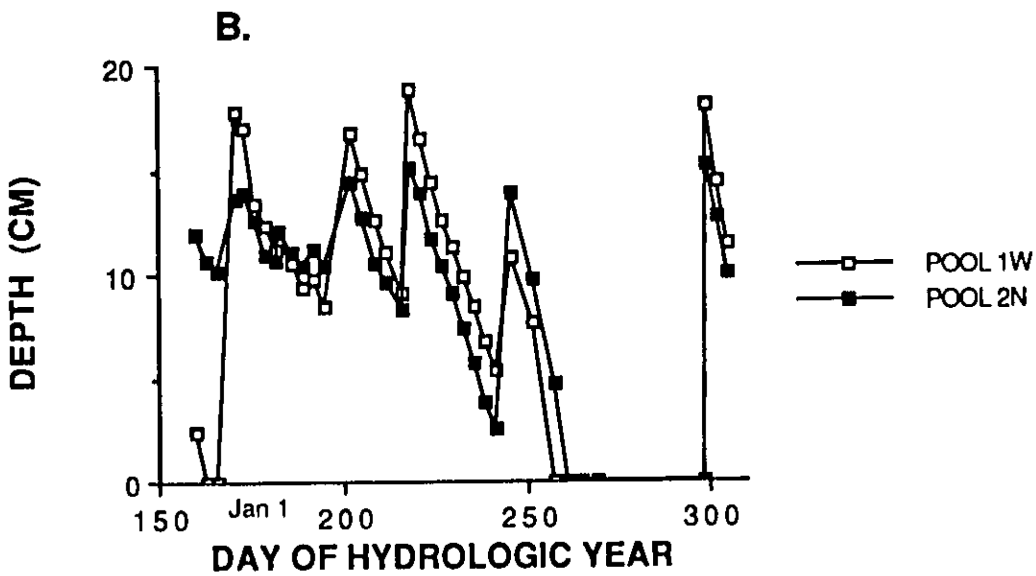
During the 5 mo when pools held water, the mean water depth was significantly greater in pools which were not recontoured and decompacted (x= 11.5 cm ± 6.11) compared to recontoured pools (x= 6.7 cm ± 5.7) (ANOVA: F= 54.108; df= 1, 328; p= 0.0001). The pattern of water retention differed in two of the recontoured pools, with soil completely exposed 5 times or more (Fig. 4A). In the remaining six pools soil was exposed only 1-2 times before the final draining (Fig. 4 B-D). The seeding and contouring treatments did not have a significant effect on the total plant cover or on the cover of three of the most common pool species (*Downingia cuspidata, Eryngium aristulatum* var. *parishii*, or *Psilocarphus brevissimus*). For *Pogogyne abramsii* cover the interaction of seeding and contouring was significant (ANOVA: F= 90.962; df= 1,4; p= 0.0007) with 19.5 percent cover in seeded, recontoured pools, 4.5 percent cover in seeded only pools, < 1 percent cover in unseeded, unrecontoured pools, and no presence in unseeded, recontoured pools. The regressions of total plant cover and cover of each of the four common pool species on total number of days pools were inundated were not significant. *Downingia* and *Pogogyne* did have a pattern of peak cover in pools with intermediate length of inundation; *Eryngium* was most common in pools with long durations; and *Psilocarphus* showed no pattern. However these results are confounded by the seeding and contouring treatments which appear to have had more impact

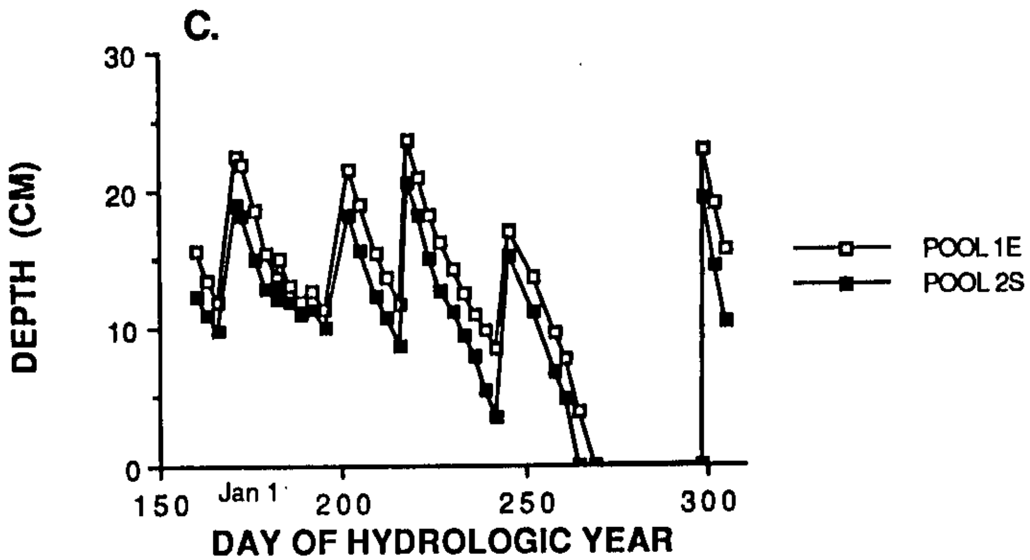
Table 1. Proportion of quadrats in four categories on transects with *Polypogon monspeliensis* removed or not. Categories are A) only *Pogogyne abramsii* present, B) only *Polypogon* present, C) Neither *Polypogon* nor *Pogogyne* present, D) *Pogogyne* and *Polypogon* both present. Values are means ± standard deviations.

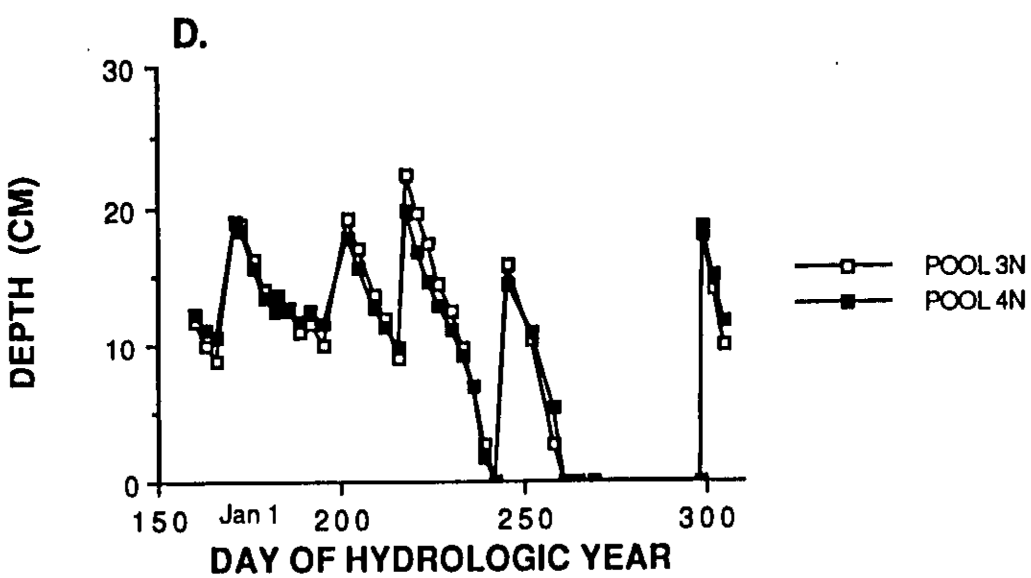
	Polypogon Removed	*Polypogon* Not-removed	*t*	p
Pogogyne abramsii	0.175 ± 0.068 (N= 6)	0.056 ± 0.053 (N=6)	3.375	0.0071
Polypogon monspeliensis	0.227 ±0.118 (N= 6)	0.484 ± 0.164 (N=6)	3.115	0.011
Neither species	0.235 ± 0.164 (N= 6)	0.580 ± 0.410 (N=6)	1.918	0.0841
Both Species	0.391 ± 0.180 (N= 6)	0.235 ± 0.126 (N= 6)	1.74	0.1115

Figure 4. Water depth in road pools versus day of hydrologic year, 1987/1988. Hydrologic years begin July 1 and end the following June 30. A and B) Pools with decompacted and recontoured soil. C and D) Pools with untreated soils.


A.
20
10
0
DEPTH (CM)
150
Jan 1
200
250
300
DAY OF HYDROLOGIC YEAR
POOL 3S
POOL 4S


B.
20
10
0
DEPTH (CM)
150
Jan 1
200
250
300
DAY OF HYDROLOGIC YEAR
POOL 1W
POOL 2N


C.
30
20
10
0
DEPTH (CM)
150
Jan 1
200
250
300
DAY OF HYDROLOGIC YEAR
POOL 1E
POOL 2S


D.
30
20
10
0
DEPTH (CM)
150
Jan 1
200
250
300
DAY OF HYDROLOGIC YEAR
POOL 3N
POOL 4N

than water duration. For the three annuals (*Downingia*, *Pogogyne*, and *Psilocarphus*) the highest cover was in pools which had intermediate water durations, but these were the four seeded pools.

Treatments had little effect on the total number of species in each pool or the number of the 16 most common native pool species present in each pool (Table 2).

DISCUSSION

Weed Removal

Removal of whole *Polypogon monspeliensis* plants--including ripened seed heads-- had a positive effect on the frequency of *Pogogyne abramsii* occurrence in the following season. Overall frequency of quadrats with *Pogogyne* was greater in weeded transects, as was the number of quadrats where *Pogogyne* occurred without any *Polypogon*. Previous work has indicated that *Pogogyne* has higher mortality and lower biomass when growing at high density, both in mono and mixed cultures (Bauder 1987b). Removal of *Polypogon* thatch may also have contributed to the increased *Pogogyne* frequency.

TABLE 2. Species present in road pools used in enhancement experiment.

	RECONTOURED				NOT RECONTOURED			
	SEEDED		UNSEEDED		SEEDED		UNSEEDED	
SPECIES*	Pool 1	Pool 2	Pool 1	Pool 2	Pool 1	Pool 2	Pool 1	Pool 2
ANAGALLIS#		X	X	X		X	X	X
AVENA		X		X				
BRODIAEA#		X		X	X	X		
BROMUS MOL	X	X	X	X	X	X	X	X
CALLITRICHE#	X	X	X	X	X	X	X	X
CHAETOPAPPA							X	
COTULA	X	X	X	X	X	X		X
CRASSULA AQ#	X	X	X	X	X	X	X	X
CRASSULA ER		X					X	
DESCHAMPSIA#	X	X	X		X	X	X	X
DOWNINGIA#	X	X	X	X	X	X	X	X
ELATINE#		X	X	X	X	X		X
ELEOCHARIS#			X			X		X
ERODIUM	X	X	X	X	X	X	X	X
ERYNGIUM#	X	X		X	X		X	
FESTUCA	X	X	X	X	X	X	X	X
FILAGO					X		X	X
GASTRIDIUM	X	X	X		X	X	X	X
HEMIZONIA	X	X	X	X	X	X	X	X
HYPOCHOERIS	X	X	X		X	X	X	X
ISOETES#	X	X					X	
JUNCUS#	X	X	X	X	X	X		X
LILAEA#	X	X	X		X	X	X	X
LYTHRUM#	X	X	X	X	X	X		X
NAVARRETIA	X	X					X	
ORTHOCARPUS		X		X				
PILULARIA#	X		X		X	X	X	X
PLAGIOBOTHRYS#			X				X	X
PLANTAGO BIG	X	X		X	X	X	X	
PLANTAGO ER							X	
POGOGYNE#	X	X			X	X	X	
POLYPOGON	X	X	X		X	X	X	X
PSILOCAR BREV#	X	X	X	X	X	X	X	X
PSILOCAR TEN		X		X			X	
SILENE				X				
SISYRINCHIUM	X			X			X	
SONCHUS							X	
SPERGULARIA			X	X	X	X	X	X
UNKNOWN	X			X		X	X	
	X					X		
TOTAL (All species)	25	28	20	23	24	26	30	23
TOTAL (Native pool sp)	12	15	13	10	13	14	12	14

NATIVE POOL SPECIES

* COMPLETE SPECIES LIST IN APPENDIX I

The weeding took place in early fall when many of the *Polypogon* seeds had already fallen to the ground. If seed heads were clipped in late spring, a greater reduction in the next year's population of *Polypogon* might be accomplished. The seed heads are compact and rise above the native vernal pool vegetation on culms 15-50 cm tall. *Polypogon* flowers late in the season, usually at about the same time as *Pogogyne* flowers. Clipping could be done soon thereafter. Clipping would have to be done several years in a row since *Polypogon* population size varies greatly from year to year, and a substantial number of seeds are stored in the soil. Three of the five pools chosen for the experiment because of their dense *Polypogon* populations in 1986/87, were nearly devoid of the grass in 1987/88. Field observations suggest that *Polypogon* does best in longer duration pools, and the three experimental pools where it was absent in 1988 were shallower than the two where it was abundant.

Road Pool Enhancement

Recontouring and decompaction of soils clearly reduced the length of pools' inundation period, and in two of the four pools resulted in more frequent exposure of the soil surface. In all eight pools the length of inundation was within the range of relatively undisturbed natural pools, but with the exception of two of the recontoured pools, these durations were at the high end of inundation periods observed in less disturbed pools (Bauder 1987b, Zedler 1987a). Beyond the change in duration length and pattern, the most obvious effect of recontouring was to improve the appearance of the pools. Also, a more gradual elevation gradient was re-established. Over the long term this ought to increase habitat for plants which thrive in pool regions where inundation length is intermediate. In pools with no recontouring, vernal pool plants were abundant in deep ruts, but absent from the adjacent humps.

The only significant effect of seeding was to increase the frequency of *Pogogyne abramsii.* When seeding was combined with recontouring, *Pogogyne* frequency was highest. Presumably this resulted from the favorable seed bed created when the hard surface crust of the soil was broken up and to the increase in the amount of habitat with intermediate duration . Other species which did not respond as well this year, may do so in subsequent years when weather conditions are different. There is a complex interplay between year-to-year variation in amount and pattern of precipitation and the requirements of individual species for successful germination, growth, and reproduction (Bauder 1987b). This means that 5-10 yr must pass before a full assessment can be made of the effects of disturbance by digging, alteration of water duration length and pattern, and augmentation of the seed bank.

When vernal pools have suffered damage from vehicles, the most important element in their recovery is protection from future vehicle trespass. If they are downslope from less disturbed pools, reintroduction of extirpated species ought to occur naturally-- given sufficient time without disturbance. Where this is not likely, seeds of native species might be introduced. If possible, seeds should be hand collected so that voluminous quantities of seeds from exotics are not also brought in. In addition, the seeds of native pool species should be from adjacent pools to reduce the possibility of significant alteration of the local gene pool.

In the case of *Pogogyne* , seeding was most effective when accompanied by recontouring. During this one season, recontouring did not serve to augment the populations of other vernal pool species, but there is the potential for a significant positive effect when the physical and biological environment have adjusted to the changes caused by soil disturbance, alteration of water durations, and re-establishment of the flora.

ACKNOWLEDGMENTS

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APPENDIX I

Anagallis minimus
Avena spp.
Brodiaea orcuttii
Bromus mollis
Callitriche marginata
Chaetopappa aurea
Cotula coronopifolia
Crassula aquatica
Crassula erecta
Deschampsia danthonioides
Downingia cuspidata
Elatine brachysperma
Eleocharis macrostachys
Erodium botrys
Eryngium aristulatum var. *parishii*
Festuca myuros (Vulpia myuros)
Filago californica
Gastridium ventricosum
Hemizonia californica
Hypochoeris glabra
Isoetes orcuttii
Juncus bufonius
Lilaea scilloides
Lythrum hyssopifolia
Navarretia hamata
Orthocarpus purpurascens
Pilularia americana
Plagiobothrys cf. *undulatus*
Plantago bigelovii
Plantago erecta
Pogogyne abramsii
Polypogon monspeliensis
Psilocarphus brevissimus
Psilocarphus tenellus
Silene gallica
Sisyrinchium bella
Sonchus asper
Spergularia sp.