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VERNAL POOL ENHANCEMENT
PHASE II

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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. Beginning in the fall of 1987, a two-factor experiment was begun using seeding (added or not added) and pool recontouring and decompaction (dug or not) as the factors. Treatments were applied to eight pools, with 2 pools in each treatment combination. During the winters of 1987/88 and 1988/89, water depth in pools was monitored at regular intervals. In the spring of 1988 and 1989, transects were sampled for the presence of all vascular plant species. After vegetation sampling in 1989, microtopography was determined along two transects in each pool.

Frequency of Pogogyne abramsii was significantly greater in seeded pools, and in both years was highest in pools with both the recontouring and seeding treatments. 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), although in both years there was a trend towards more pool species in seeded compared to unseeded pools.

Recontouring of pools altered the microtopography of pool basins, creating more gentle slopes and fewer pits or ruts. These pools also were less likely to retain water which resulted in inundation periods closer to those found in pools undamaged by vehicles. Recontoured pools had more area with intermediate length of inundation because of their altered slope and changed water retention characteristics. The vegetation data from 1989 strongly suggest that recontouring favored population stability of two important vernal pools species : Downingia cuspidata and Pogogyne abramsii.

Many of San Diego's vernal pools have vehicle damage which varies greatly in degree of severity. Successful rehabilitation of even a portion of these damaged pools would be of great value since so few pools remain, with or without vehicle damage.

INTRODUCTION

While construction is the primary threat to San Diego County's remaining vernal pools, damage by vehicles has 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 months, 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). Vehicles also create deep ruts and pits in pools, producing a corduroy effect of alternating ridges and steep-sided depressions. This reduces the amount of habitat with gently sloping sides and intermediate length of inundation. Holland and Jain (1984) found that the number of taxa specialized for a given pool depth is proportional to the relative area in a pool at that depth. Thus, reduction in amount of habitat with intermediate periods of inundation might eliminate or reduce populations of species adapted to this water regime.

The purpose of this study was to investigate ways to enhance the quality of pools which have been damaged by vehicles. A road pool enhancement experiment was carried out during the 1987/1988 (Bauder 1988) and 1988/1989 growing seasons. This 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 winters of 1987/88 and 1988/89, water depth in pools was monitored at regular intervals. In the spring months of 1988 and 1989 transects were sampled for the presence of all vascular plant species. In June, 1989 relative elevations were determined for two transects at right angles to each other in each of the pools, to determine the effect of digging on pool micro-topography and also the interaction of topography with water depth and distribution of vegetation.

A recent survey (Bauder 1986) of San Diego pools was used to develop a list of potential sites to apply the enhancement and restoration techniques which the current study indicates will be successful.

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, 1987 the "Landmark" was surveyed for possible sites for the project. At this time, 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. On the basis of this information, eight pools were chosen for the study.

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 which have repeatedly been 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 without large grading machinery. 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. Elevation transects (See below) taken in spring, 1989 confirmed that the water measurement stakes were at the lowest point in 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 for the 1987/1988 hydrological year and November 25, 1988 for the 1988/89 hydrological year. 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.

In 1988, point-frame sampling of vegetation transects was begun in late March, when all pools had drained and dried, and sampling was completed a month later. The following year vegetation sampling was done at approximately the same time. 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. 1). 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 in 1988 the species present at each of the 55 points were recorded. In 1989, only ten species plus plant cover were sampled using this method. The species were Deschampsia danthonioides, Downingia cuspidata, Erodium botrys, Eryngium aristulatum var. parishii, Hypochoeris glabra, Lythrum hyssopifolia, Pogogyne abramsii, Polypogon monspeliensis, Psilocarphus brevissimus, and Vulpia myuros. For all other species, presence or absence in the quadrat was recorded. The frame was moved along the transect until all 30 cm-intervals were sampled.

Along two transects in each pool, relative elevation was taken at 1 dm intervals using a surveyor's level and stadium rod. In each pool the elevation transects were laid out perpendicular to each other with their intersection at the water measurement stake. The transect at right angles to the road bed thus coincided with the middle of the three vegetation transects (Fig.1). This made it possible to assign an elevation to each vegetation quadrat. In addition, the relative elevation of the water measurement stake was taken, and maximum water depth for both years was calculated at 1 dm intervals along the elevation/vegetation transect. This information made it possible to correlate the distribution

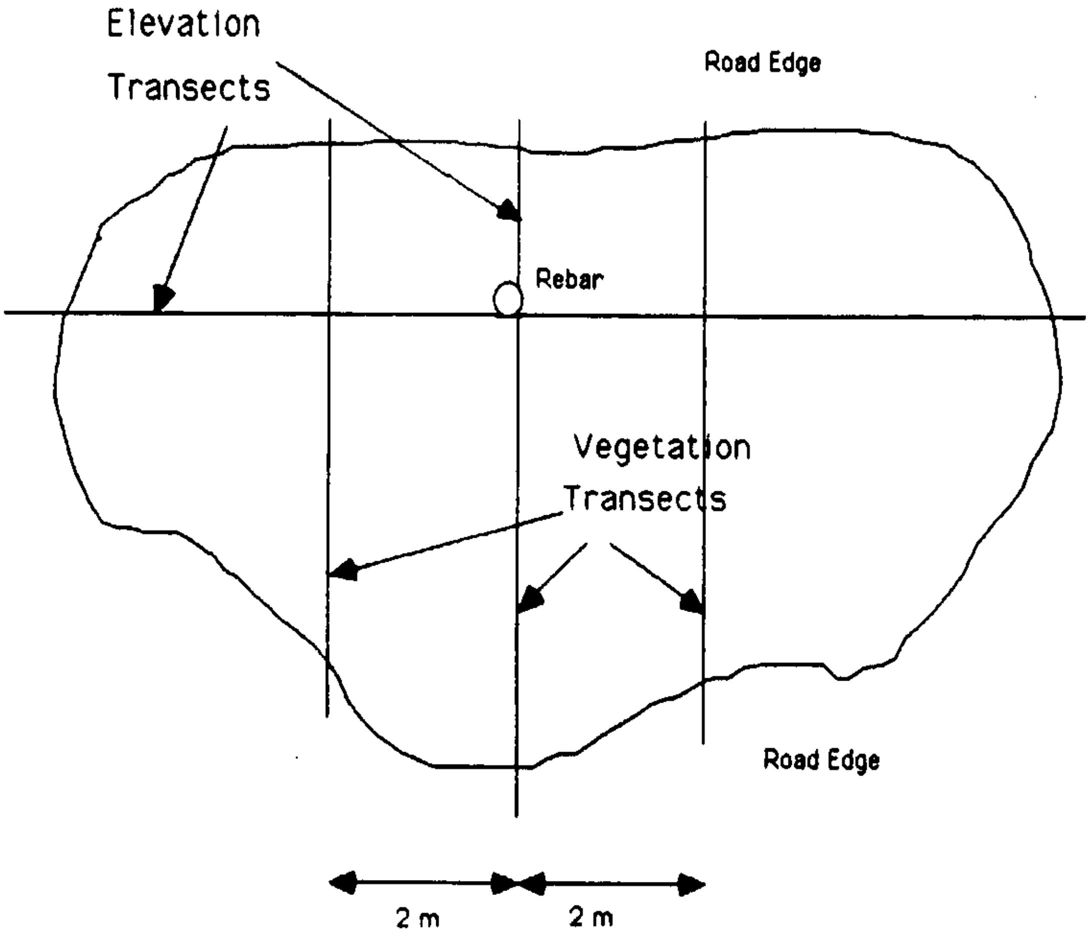


Figure 1 .Vegetation and elevation transects.

of the various plant species with pool topography and water depth. It also demonstrated the effectiveness of recontouring and the extent of deformation in unrecontoured pools.

Data analysis

Unless otherwise noted in the text, vegetation analysis employs pooled data from the three vegetation transects within each pool, yielding a single value per pool. Vegetation data taken in 1988 by the point-intercept method were converted to quadrat presence/absence data. ANOVA and regression analysis indicated that there were no differences in conclusions to be drawn from the two types of information. Consequently, all 1988 and 1989 data were converted to the quadrat presence/absence form. Sampling by quadrats was much quicker, especially in the dry year, and it was believed that this method would reduce the number of errors inherent in the more tedious and exacting point/intercept method. Also, frequency of many pool plants was quite low in 1989, and the quadrat form of data collection eliminated many zeroes from the analysis. Analysis of percent plant cover was based on point/intercept data in both years. All statistical tests performed on percentages or proportions used arcsine transformed data. Number of species per road pool was estimated from transect data and not complete surveys of each pool.

Potential restoration sites

A recent survey (Bauder 1986) of the status and condition of San Diego's vernal pools was used to create a list of possible restoration/rehabilitation sites. Because of the rapid pace of land development in San Diego County, the status and condition of some of these pools may no longer be as reported in 1986. In addition, new projects may have resulted in destruction of pools still present in 1986. Recommendations made here are based on the potential of the pools for successful restoration, and are not intended to be evidence for their availability. Site rechecks were not made.

RESULTS

Water retention

In the 1989 hydrological year, the mean water depth was greater in recontoured pools ($\bar{x}$= 3.15 cm ± 0.88), compared to undug pools ($\bar{x}$= 1.72 cm ± 1.6), but this difference was not significant. Pools retained the individual water retention characteristics observed in 1987/88 (Table 1). Those which held water for the most days in the 1987/88, did so in the following year, although the lack of precipitation in 1988/89 resulted in much shorter periods of inundation, reduced mean depth, and fewer total days inundated (Fig. 2). The total precipitation in 1987/88 at Lindberg Field was 33.5 cm or 41% above the long term mean of 23.7 cm. However, in 1988/89 the total precipitation was 14.4 cm or 61% of the mean. Pools which tended not to hold water well had the most fluctuation in water level in wet years, but the least in dry years. This can be seen in the number of times pools accumulated enough water to measure (Table 1). In 1987/88 the two pools which drained most rapidly had standing water followed by complete soil exposure 6-7 times. In 1988/89, this lack of water retention resulted in standing water only twice, whereas pools more likely to retain water fluctuated between inundation and exposure 3-5 times. In the previous year these "high retention" pools had exposure only 2-3 times.

Basin Contours

Deformity of pool basins was most obvious along elevation transects perpendicular to the roadway. Ruts are evident in the elevation transects of undug Pools 2S, 3N, and 4N (Figs. 3A, 4, and 5). Ruts were eliminated in recontoured Pools 1W, 3S, and 4S (Figs. 6, 7, and 8), but a deep pit remained in Pool 1W on the transect parallel to the road (Fig. 9A). Ruts were still evident in recontoured Pool 2N (Fig. 3B), but these may have been caused by a trespassing vehicle which crossed the pool in the late spring (1988) after treatment. Undug Pool 1E did not have particularly deep ruts in a transect perpendicular to the road (Fig. 10), but was severely deformed along the transect parallel to the road (Fig. 9B). In the past vehicles have become mired in this pool, so the lack of well-defined parallel tire ruts is not too surprising.

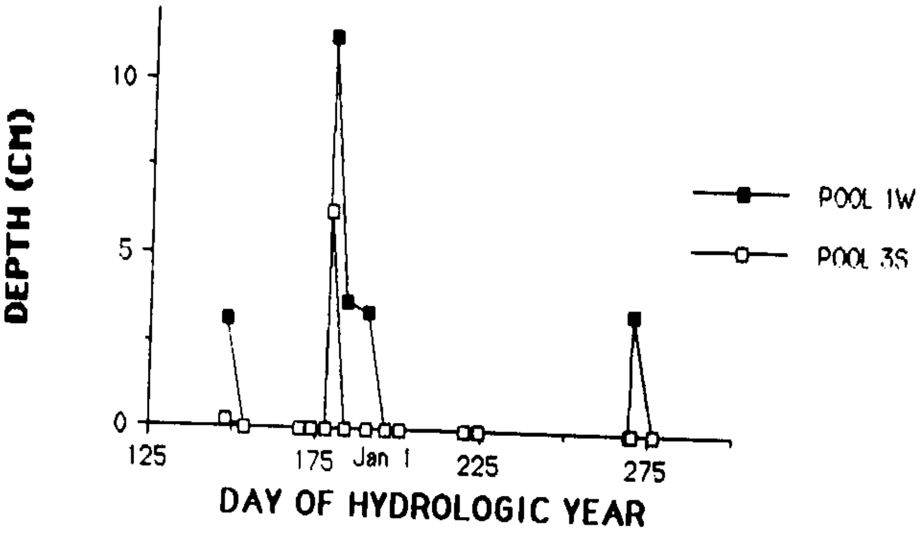
Interaction of Basin Contours with Water Retention and Vegetation

In 1988/89, pools with deep ruts filled with water only in the ruts (Figs. 3,4, and 5). In the three successfully recontoured pools, water spread out and covered more surface area. This was especially evident in Pools 1W and 4S (Figs. 6 and 8). Plant distributions were related to the surface area inundated. *Pogogyne abramsii* occurred only in the four

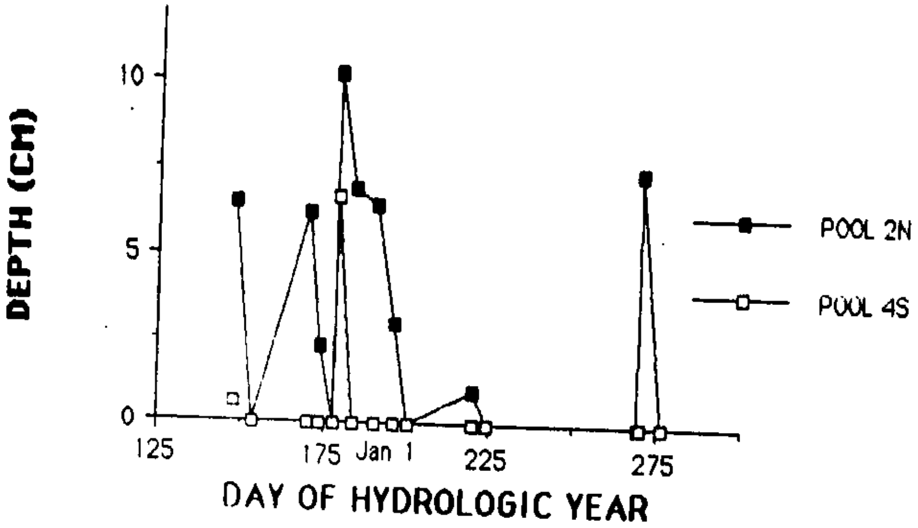
Table 1. Water retention characteristics of dug and undug pools in 1988 and 1989. Data were taken at the lowest elevation in each pool. Tot.= total number of days inundated; Mn.= mean water depth; Cont.= longest continuous period inundated;# Times= number of times inundated.

	1988				1989			
Pool	Tot.	Mn.	Cont.	#Times	Tot.	Mn.	Cont.	#Times
DUG								
1W	107	9.1	88	3	24	1.9	12	3
2N	118	9.7	104	2	46	3.9	20	5
3S	76	5.5	32	6	7	0.5	5	2
4S	51	3.3	19	7	7	0.6	4	2
UNDUG								
1E	128	13.7	112	2	40	4.1	20	5
2S	122	11.5	108	2	24	2.2	12	4
3N	105	11.6	85	3	27	2.7	12	4
4N	105	11.2	85	3	34	3.7	20	3

Figure 2. Water depth in road pools versus day of hydrologic year, 1988/1989. Hydrologic years begin July 1 and end the following June 30. A and B) Pools with decompacted soil and recontoured basins. C and D) Pools with untreated soils.

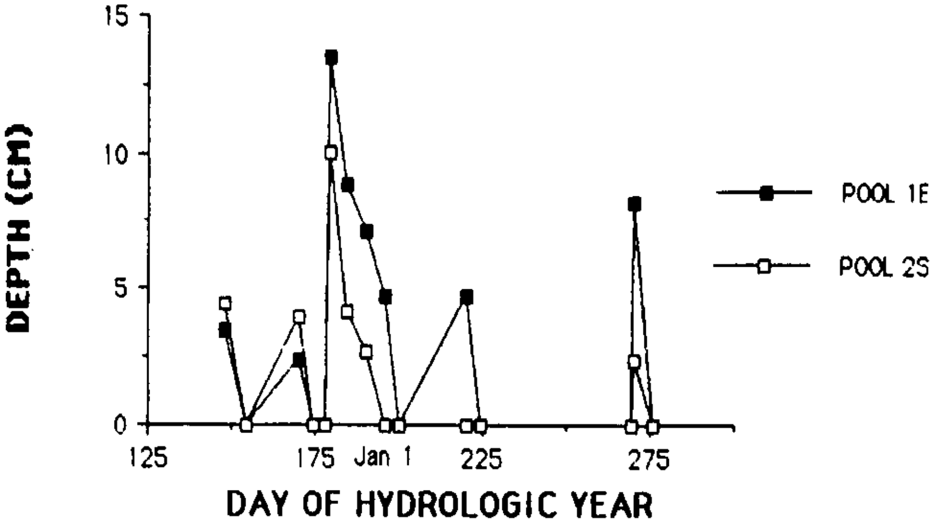


A. RECONTOURED POOLS



B. RECONTOURED POOLS

C. UNRECONTOURED POOLS



D. UNRECONTOURED POOLS

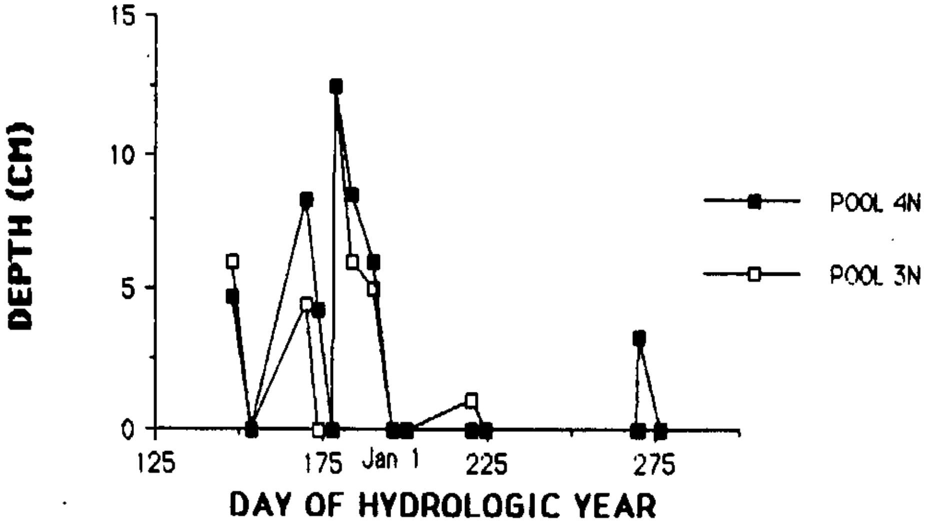
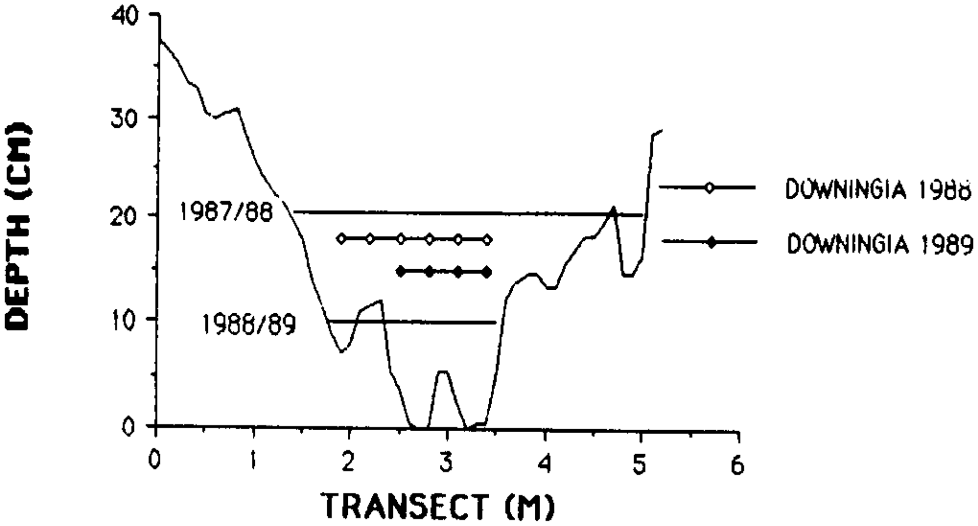


Figure 3. Distribution of Downingia cuspidata in relation to microtopography and water depth in: A) an unseeded recontoured pool (2S) and B) an unseeded unrecontoured pool (2N). Horizontal straight lines indicate the maximum water depth in 1987/88 (top) and 1988/89 (bottom). Each symbol indicates Downingia presence in one 30 cm X 15 cm quadrat.

A. RECONTOURED POOL (2S)



B. UNRECONTOURED POOL (2N)

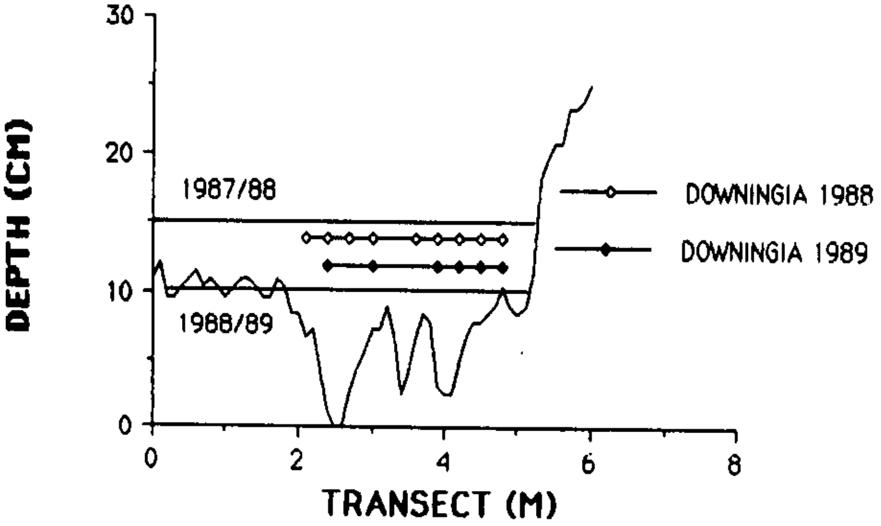
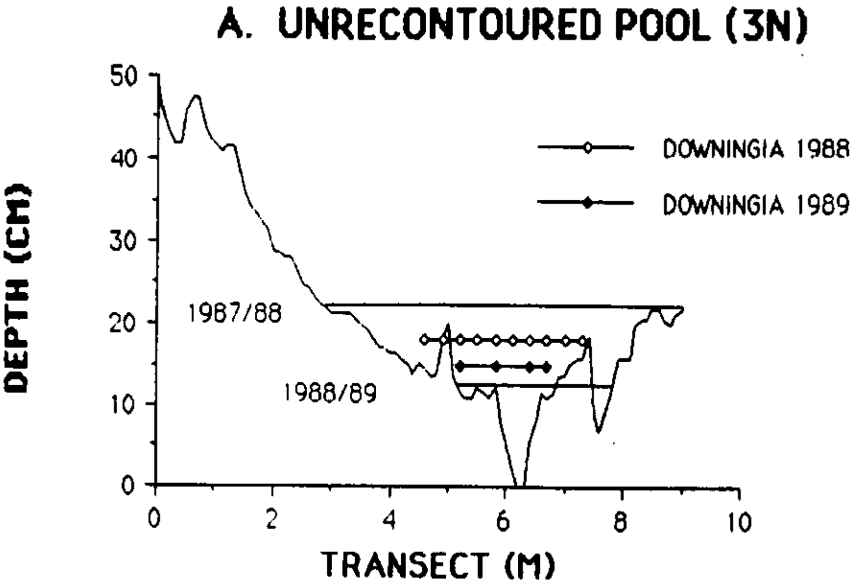


Figure 4. Distribution of: A) *Downingia cuspidata* and B) *Pogogyne abramsii* in relation to micro-topography and water depth in a seeded unrecontoured pool (3N). Horizontal straight lines indicate the maximum water depth in 1987/88 (top) and 1988/89 (bottom). Each symbol indicates *Downingia* or *Pogogyne* presence in one 30 cm X 15 cm quadrat.


A. UNRECONTOURED POOL (3N)

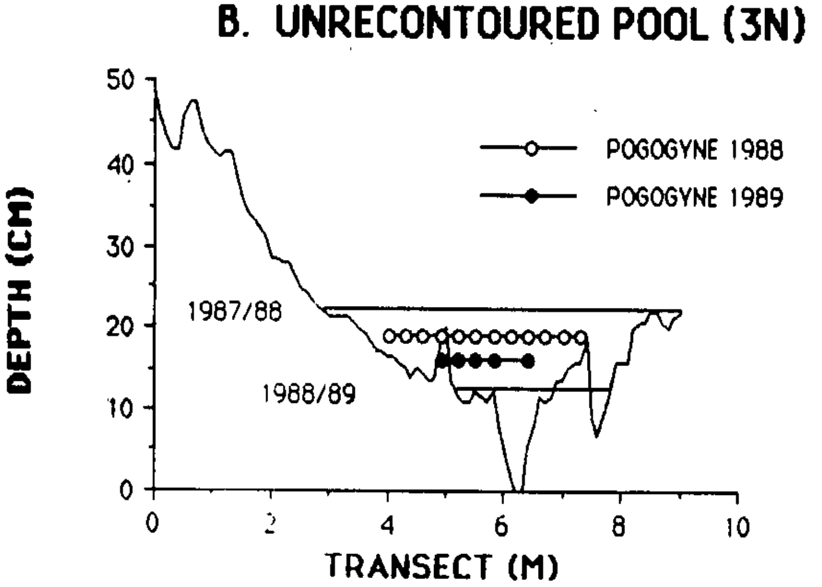
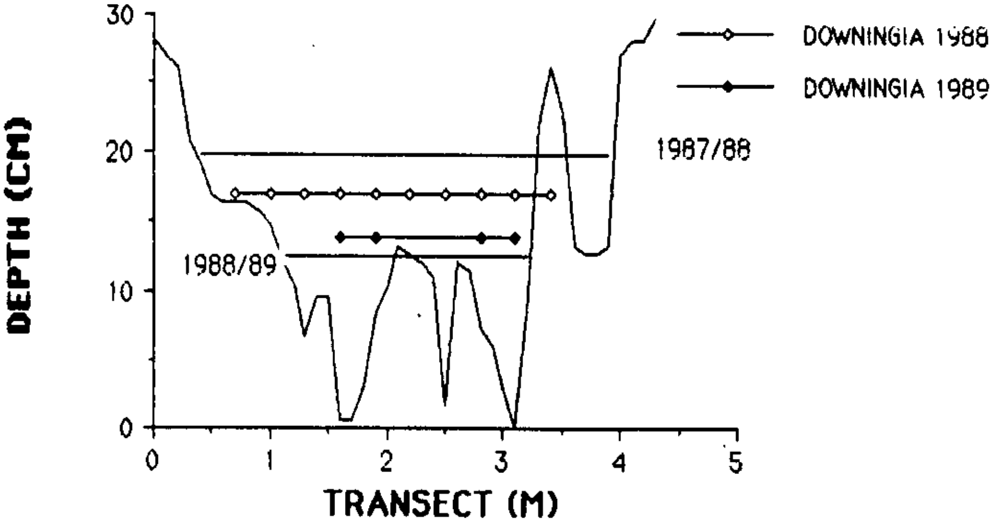

B. UNRECONTOURED POOL (3N)

Figure 5. Distribution of: A) Downingia cuspidata and B) Pogogyne abramsii in relation to micro-topography and water depth in a seeded unrecontoured pool (4N). Horizontal straight lines indicate the maximum water depth in 1987/88 (top) and 1988/89 (bottom). Each symbol indicates Downingia or Pogogyne presence in one 30 cm X 15 cm quadrat.

A. UNRECONTOURED POOL (4N)



B. UNRECONTOURED POOL (4N)

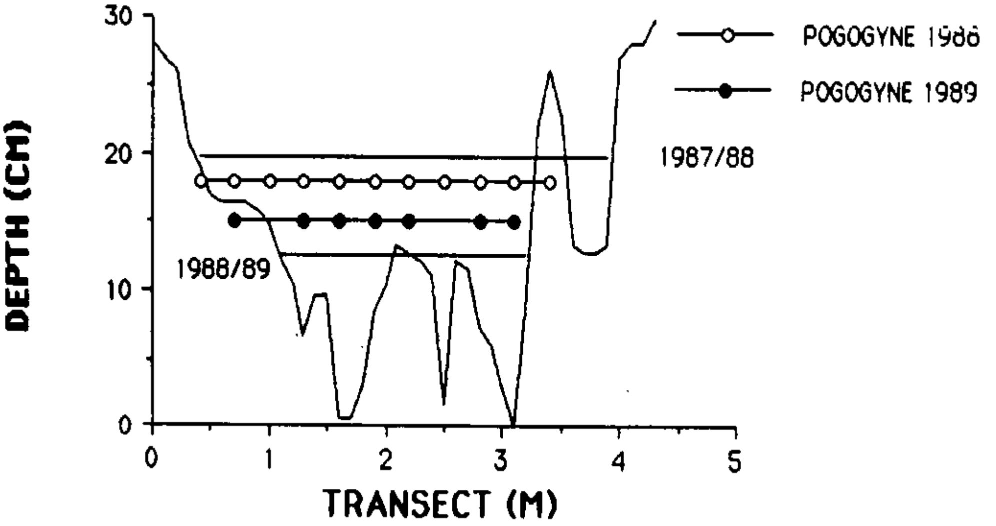
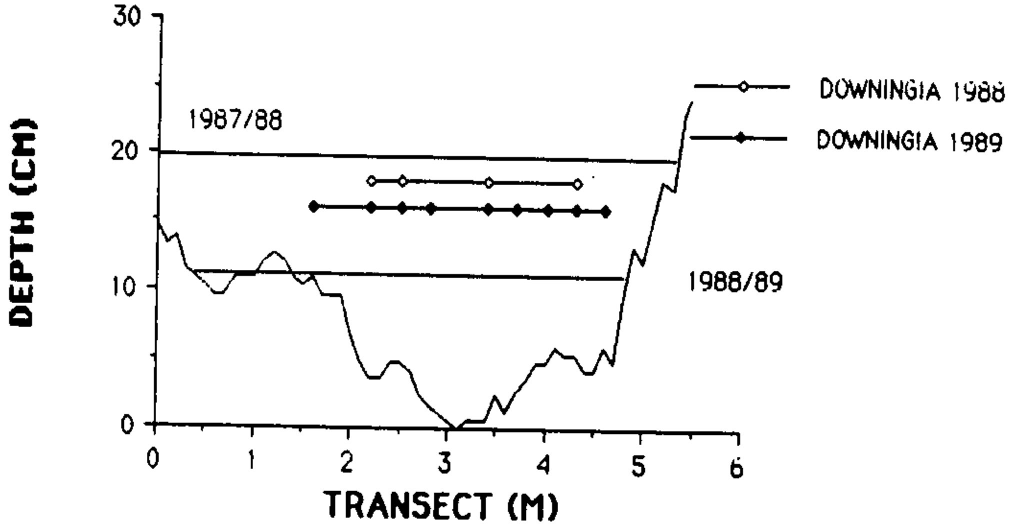
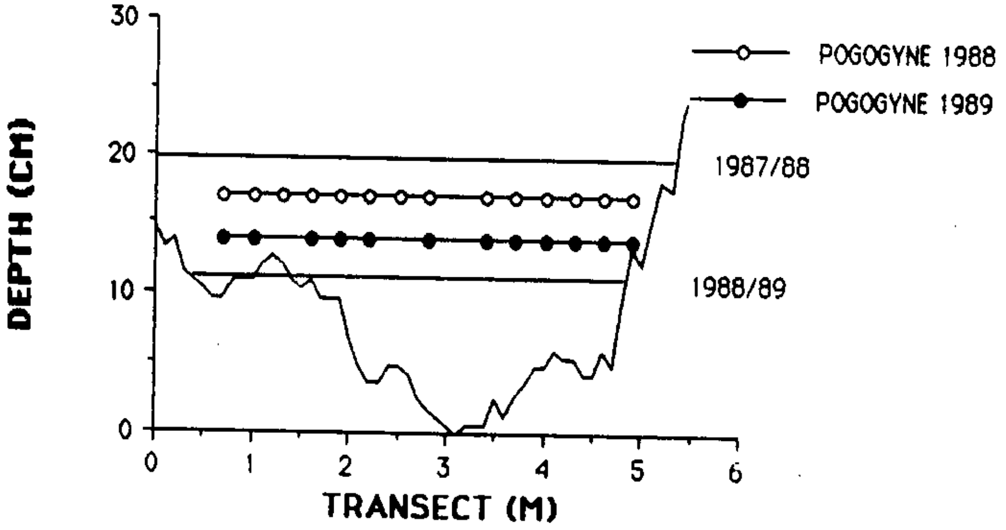


Figure 6. Distribution of: A) Downingia cuspidata and B) Pogogyne abramsii in relation to micro-topography and water depth in a seeded recontoured pool (1W). Horizontal straight lines indicate the maximum water depth in 1987/88 (top) and 1988/89 (bottom). Each symbol indicates Downingia or Pogogyne presence in one 30 cm X 15 cm quadrat.

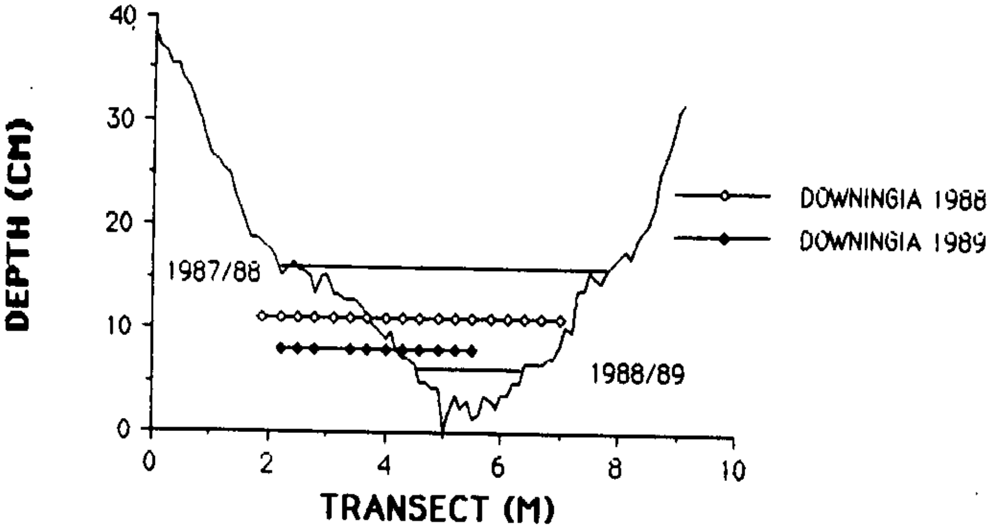


A. RECONTOURED POOL (1W)

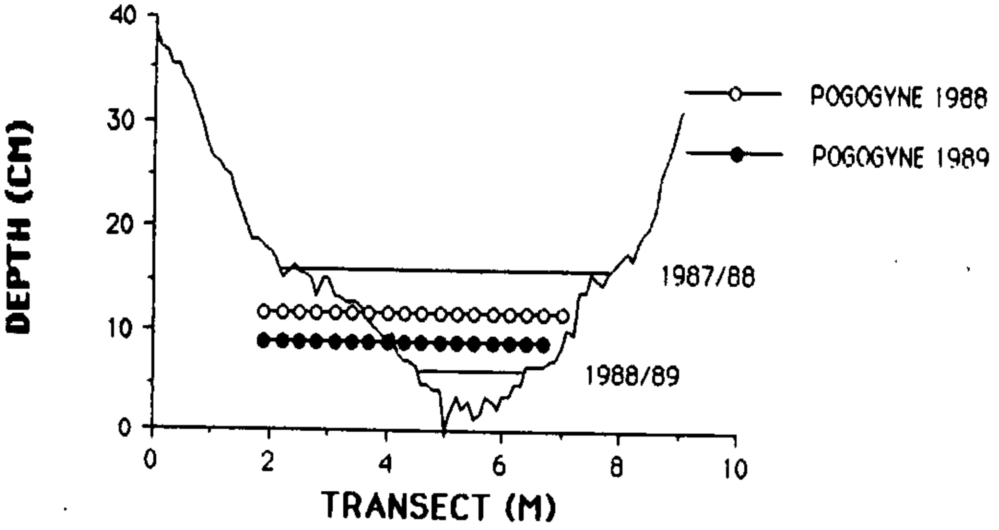


B. RECONTOURED POOL (1W)

Figure 7. Distribution of: A) Downingia cuspidata and B) Pogogyne abramsii in relation to micro-topography and water depth in a seeded recontoured pool (3S). Horizontal straight lines indicate the maximum water depth in 1987/88 (top) and 1988/89 (bottom). Each symbol indicates Downingia or Pogogyne presence in one 30 cm X 15 cm quadrat.

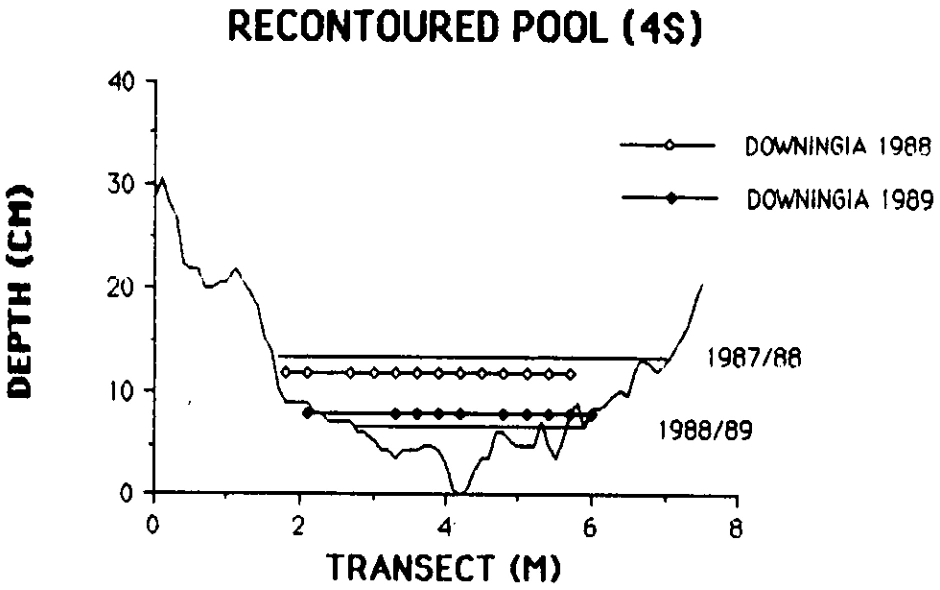


A. RECONTOURED POOL (3S)



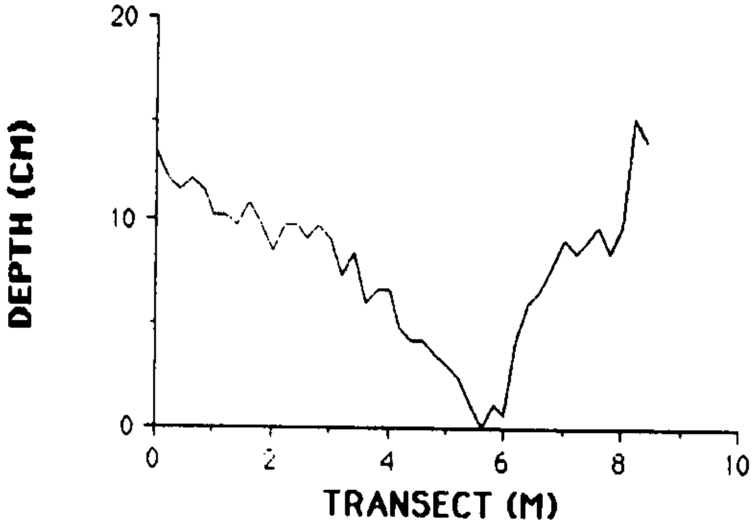
B. RECONTOURED POOL (3S)

Figure 8. Distribution of Downingia cuspidata in relation to microtopography and water depth in an unseeded recontoured pool (4S). Horizontal straight lines indicate the maximum water depth in 1987/88 (top) and 1988/89 (bottom). Each symbol indicates Downingia presence in one 30 cm X 15 cm quadrat.



RECONTOURED POOL (4S)

Figure 9. Microtopography along transects parallel to the roadbed in: A) a recontoured pool (1W) and B) an unrecontoured pool (1E).


A. RECONTOURED POOL (1W)

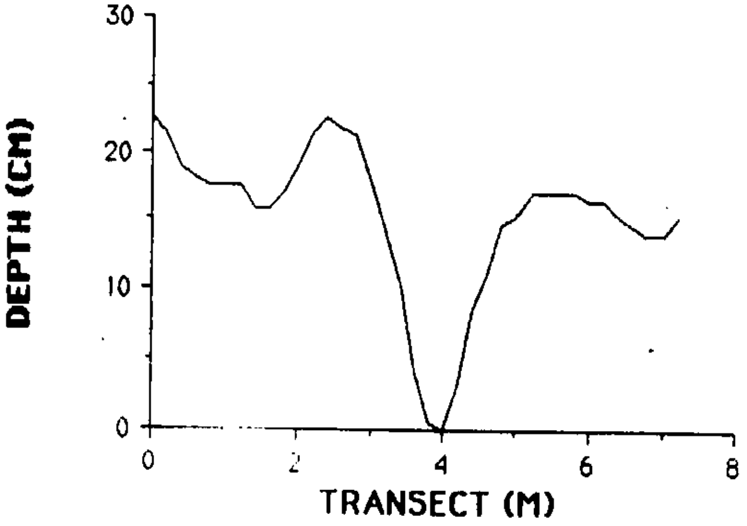
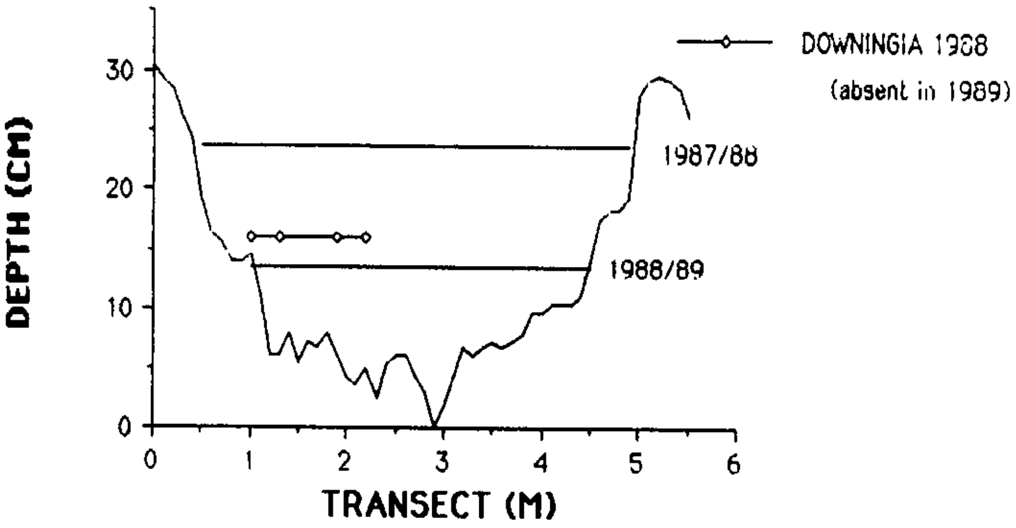

B. UNRECONTOURED POOL (1E)

Figure 10. Distribution of Downingia cuspidata in relation to microtopography along a transect at right angles to the road in an unseeded unrecontoured pool (1E). Horizontal straight lines indicate the maximum water depth in 1987/88 (top) and 1988/89 (bottom). Each symbol indicates Downingia presence in one 30 cm X 15 cm quadrat.

UNRECONTOURED POOL (1E)



seeded pools, two of which were recontoured and two left undug. In the recontoured pools (Figs. 6B and 7B), along the elevation/vegetation transect the location of quadrats with Pogogyne present differed little from 1988 to 1989, and the number of quadrats occupied changed little (32 vs. 29). In contrast, in the two undug pools (Figs. 4B and 5B), the number of quadrats with Pogogyne present dropped from 23 in 1988 to 12 in 1989, and Pogogyne was restricted in 1989 to the ruts.

The difference between dug and undug pools in distribution and frequency of Downingia cuspidata was even more apparent than with Pogogyne. In 1988 three of the undug pools had 26 quadrats on the elevation/vegetation transect with Downingia, and 12 in 1989. In these pools Downingia presence was confined totally to deep ruts in the dry year (Figs. 3A, 4A, and 5A). Undug Pool 1E had Downingia in only four quadrats along the elevation/vegetation transect in 1988 and none in 1989. In the four recontoured pools, along the elevation/vegetation transect there were 44 quadrats in 1988 with Downingia present, and 36 quadrats in 1989. In Pool 2N, where ruts remained despite the digging treatment, Downingia's range was restricted to ruts in 1989 (Fig. 3B). In the other three recontoured pools, although frequency of occupied quadrats was down, the range was unchanged (Figs. 6A, 7A, and 8), and the plants were more evenly distributed along the elevation gradient than in unrecontoured pools.

Vegetation

As in 1988, the seeding and contouring treatments did not have a significant effect on total plant cover or the cover of three of the most common pools species (Downingia cuspidata, Eryngium aristulatum var. parishii, or Psilocarphus brevissimus). Pogogyne abramsii cover was significantly greater in seeded pools compared to unseeded pools (ANOVA: F- 37.358;df- 1,4; p-0.0036). Two of the seeded and two of the unseeded pools had Pogogyne present prior to treatments being applied. The interaction of digging and seeding was not significant, as it was in 1988, but this treatment combination still resulted in greater Pogogyne cover than in the other three treatment combinations (Table 2).

Total plant cover (estimated by number of points which intercepted plants of any species) was nearly the same in 1989 compared to 1988 (70.5% vs. 70.2%), but the relative proportions of some species changed (Table 3). Most notable was the shift towards greater frequency of inundation intolerant non-pool species such as Erodium botrys and

Table 3. Percent change from 1988 to 1989 in frequency of quadrats occupied in 8 pools. Species which increased or decreased 5% or less are not included. Full species names are in Appendix 1.

Reduced Frequency		Increased Frequency	
≥ 20 %	>5<20 %	≥ 20 %	>5<20 %
Downingia	Anagallis	Erodium	Hemizonia
Juncus	Deschampsia	Hypochoeris	Plantago big.
Polypogon	Elatine		
	Lilaea		
	Pilularia		
	Pogogyne		
	Vulpia		

Hypochoeris glabra (ANOVA, repeated measures: F= 13.828, df= 1,6, p=.0099 and F= 30.112, df= 1,6, p= .0015). There was a trend towards reduced frequency of inundation tolerant pool species such as *Downingia cuspidata*, *Pogogyne abramsii*, and *Juncus bufonius*, but the difference between years was non-significant except for *Juncus* which had a significantly lower frequency in 1989 (ANOVA, repeated measures: F= 8.616, df= 1,6, p= .0261).. Of the 16 common pool species found in these pools, 7 had a frequency reduced by more than 5% (Table 3). Three of the remaining 9 species are perennials and their frequencies would not be expected to fluctuate very much year-to-year. All four species with a greater than 5% increase in frequency were non-pool species.

Digging effects on pool species were non-significant, but there was a suggestion of a positive impact on *Downingia*, *Juncus* and *Lythrum*. Likewise, digging treatment effects on the frequency of exotics such as *Erodium* and *Hypochoeris* were non-significant, but both had higher frequencies in undug pools compared to dug pools in 1988. This possible effect of digging disappeared in 1989.

Treatment effects on the number of species per pool or number of pool species per pool were non-significant, although the effect of seeding was positive and nearly significant (p= .06) (Table 4).

The regressions of total plant cover, number of pool species, and cover of each of four common pool species (*Downingia cuspidata*, *Eryngium aristulatum* var. *parishii*, *Pogogyne abramsii*, and *Psilocarphus brevissimus*) on total number of days of inundation at the lowest elevation or mean water depth at the lowest elevation were non-significant. Total plant cover tended to be less in pools with longer inundation, but the difference was non-significant (p= .06).

Potential Restoration Sites

There are many potential restoration sites in San Diego County (Table 5). Even if only one pool per series were restored, this could improve 5% or more of the pools which remain, depending on how many pools have been lost since the 1986 survey (Bauder 1986). Potential restoration sites can be placed into three large groups based on ownership: 1) public-military, 2) public- non-military, and 3) private. The best candidates for restoration are pools in public ownership, because management and protection might be accomplished more easily. Some of these pools are slated to become part of a National Wildlife Refuge which is being established to oversee the management of a

TABLE 4. Species present in road pools used in enhancement experiment (1989).

	RECONTOURED				NOT RECONTOURED			
	SEEDED		UNSEEDED		SEEDED		UNSEEDED	
	Pool 1 1 W	Pool 2 3 S	Pool 1 2 N	Pool 2 4 S	Pool 1 3 N	Pool 2 4 N	Pool 1 1 E	Pool 2 2 S
SPECIES*								
ANAGALLIS#	X	X		X		X		
AVENA	X	X		X		X		
BRODIAEA#	X	X			X	X	X	X
BROMUS MOL	X	X	X	X	X	X	X	X
BROMUS RUB		X		X		X		
CALLITRICHE#	X	X	X	X	X	X	X	X
COTULA		X	X	X	X	X		X
CRASSULA AQ#	X	X	X	X	X	X	X	X
CRASSULA ER	X			X	X		X	
DESCHAMPSIA#	X	X	X		X	X	X	X
DOWNINGIA#	X	X	X	X	X	X		X
ELEOCHARIS#			X		X	X	X	X
ERODIUM	X	X	X	X	X	X	X	X
ERYNGIUM#	X	X		X	X	X	X	
FESTUCA	X	X	X	X	X	X	X	X
FILAGO		X		X		X	X	X
GASTRIDIUM	X	X				X		X
HEMIZONIA	X	X	X	X	X	X	X	X
HYPOCHOERIS	X	X	X	X	X	X	X	X
ISOETES#	X	X	X	X	X	X	X	
JUNCUS#	X	X		X		X		X
LILAEA#			X				X	
LOTUS HAM	X							
LOTUS PURS				X		X		
LYTHRUM#	X	X	X	X	X	X	X	X
MICROSERIS	X		X				X	
NAVARRETIA	X	X					X	
ORTHOCARPUS		X		X		X		
PILULARIA#	X	X	X			X	X	
PLAGIOBOTHRYS#	X	X	X		X	X	X	X
PLANTAGO BIG	X	X	X	X	X	X	X	X
PLANTAGO ER							X	
POGOGYNE#	X	X			X	X	X	
POLYPOGON	X	X	X		X			
PSILOCAR BREV#	X	X	X	X	X	X	X	X
PSILOCAR TEN	X		X	X			X	
SISYRINCHIUM	X			X			X	
SPERGULARIA			X	X			X	X
TRIFOLIUM	X							
VERONICA	X					X		
UNKNOWN	X						X X	
TOTAL (All species)	32	28	22	26	21	30	29	20
TOTAL (Native pool species	14	14	11	9	12	15	13	10

NATIVE POOL SPECIES

* COMPLETE SPECIES LIST IN APPENDIX I

TABLE 5. Potential restoration sites. Disturbance codes: D= Alteration of drainage; E= Exotics; G= Grazing; O= Other- grading, erosion; P= pedestrians, illegal trespass on foot; T= Trash, dumping; and V= Vehicles.

POOL CODE#	REGION	JURISDICTION*	OWNERSHIP*	DISTURBANCE
A4	TIERRASANTA	CITY	CALTRANS	T,V
B5	MIRA MESA NORTH	CITY	CALTRANS	V
B7-8		CITY	CITY	O,V
C18	MIRA MESA CENTRAL	CITY	PRIVATE	D,E
D5-8	MIRA MESA SOUTH	CITY	PRIVATE	V?
F2-F17	KEARNY VILLA NORTH		US NAVY	E,T,V
F19-26			US NAVY	D,E,T,V
G1-2	TIERRASANTA SOUTH		US NAVY	O,T,V
H4	PENASQUITOS NORTH	CITY	PRIVATE	V
H5-6, 10		CITY	CALTRANS	V
H13-15		CITY	CALTRANS	V
H18-21,23		CITY	CALTRANS	V
H31-33		CITY	?	V
I1	MIRAMAR INDUSTRIAL	CITY	PRIVATE	T,V
I6A		CITY	PRIVATE	D,O,T,V
I6B		CITY	PRIVATE	D,T
I6C		CITY	PRIVATE	D,T
I7			US NAVY	V
J1	OTAY	CITY	PRIVATE	V
J2(S,N,&W)		CITY	PRIVATE	V
J3		CITY	PRIVATE	E
J4-5		CITY	PRIVATE	E,V
J7		CITY		V
J11 (E&W)		CITY	PRIVATE	P,T,V
J12		CITY	PRIVATE	P,T,V
J13N		CITY	PRIVATE	O,T,V
J13S		CITY	PRIVATE	G,V
J13E		CITY	PRIVATE	?
J14		CITY	PRIVATE	V
J15		CITY	PRIVATE	?
J16		CITY	PRIVATE	?
J17		CITY	PRIVATE	?
J18		CITY	PRIVATE	?

TABLE 5. (Continued)

POOL CODE*	REGION	JURISDICTION*	OWNERSHIP*	DISTURBANCE
J21		CITY	PRIVATE	E,T
J22		COUNTY	PRIVATE	E
J23		COUNTY	PRIVATE	E,G
J24		COUNTY	PRIVATE	E,G
J25		COUNTY	PRIVATE	E,G,O,V
J26		COUNTY	PRIVATE	V
J28		CITY	PRIVATE	E
J30		CITY	PRIVATE	E,G,V
K1	OTAY RIVER	?	PRIVATE	?
K2		COUNTY	PRIVATE	?
K6		COUNTY	PRIVATE	E,G
K7		COUNTY	PRIVATE	G
L1-6	SAN MARCOS	CITY OF SM	PRIVATE	T,V
L9-10		CITY OF SM	PRIVATE	?
L11-13		CITY OF SM	PRIVATE	D,T, V(?)
M2	CHULA VISTA	COUNTY	PRIVATE	V
M4		COUNTY	COUNTY	T,V
N1-4, 6	MONTGOMERY FIELD	CITY	CITY	D,E,O
O1	MISSION VILLAGE	CITY	PRIVATE	V
Q1	GROSSMONT COLLEGE	SANTEE	PRIVATE	T,V
R1	PROCTOR VALLEY	COUNTY	CITY	G,V
S1-3	SWEETWATER LAKE	COUNTY	GENERAL TELEPHONE SOUTH BAY IRRIGATION	E
T1-5	RAMONA	COUNTY	PRIVATE	E,G
T6+		COUNTY	PRIVATE	T,V
T7+		COUNTY	PRIVATE	T,V
U1-13	LANDMARK		US NAVY	D,E,T,V
U15			US NAVY	V
U18		CITY	CITY	D,T
W1-2	SOUTH MIRAMAR NAS		US NAVY	O,T
W3			US NAVY	T,V
X1-4	WEST MIRAMAR NAS		US NAVY	T,V

TABLE 5. (Continued)

POOL CODE#	REGION	JURISDICTION*	OWNERSHIP*	DISTURBANCE
Y1-4	CAMP PENDLETON		US MARINES	V
Y5			US MARINES	O,V
Y6			UW MARINES	V
Z1-5	WEST GATE MIRAMAR NAS		US NAVY	V
Z6-7			US NAVY	V
Z8			US NAVY	?
AA1	WEST MIRAMAR NAS		US NAVY	V?
AA2			US NAVY	V?
AA4-7			US NAVY	O,V
AA8			US NAVY	V
AA9			US NAVY	D,V
AA10			US NAVY	V
AA11			US NAVY	V?
AA12			US NAVY	V?
AA13			US NAVY	O,V
AA14+			US NAVY	T,V
DD4	RANCHO BERNARDO	CITY	PRIVATE	O,V
EE1	MIRAMAR NAS INTERIOR		US NAVY	T,V
EE2			US NAVY	T,V
FF1			US NAVY	?
FF2			USNAVY	?
GG			US NAVY	V
HH			US NAVY	D,V
RR1-2			US NAVY	V?

*CITY= CITY OF SAN DIEGO UNLESS OTHERWISE NOTED. COUNTY= SAN DIEGO COUNTY
CODES FOLLOWED BY "+" ARE NEWLY MAPPED.

number of vernal pools in San Diego County (N. Gilbert, US Fish and Wildlife Service).

Many privately owned pools could benefit from restoration or rehabilitation efforts, but improvements would be short lived unless the land is purchased or land owner protection agreements are signed. Especially important in this category are the Otay Mesa, San Marcos, and Ramona pools because they represent substrate types and species not found on the central San Diego Mesas.

DISCUSSION

Recontouring and decompaction of soils eliminated deep ruts and restored the gentle slope typical of undisturbed pools (Bauder 1987). This resulted in a more stable distribution of two pool species, Downingia cuspidata and Pogogyne abramsii. In recontoured pools,the difference in precipitation and length of inundation did not affect between year distributions of these species along the elevation transect and had only a slight effect on their frequency. In the dry year of 1988/89, in undug pools these two species were confined to ruts and were much reduced in frequency. If next year has average or above average precipitation, their range in the undug pools might expand to match that in 1987/88, if seed storage in the soil is sufficient. Both species have substantial seed storage in the soil if moisture is inadequate for germination (Bauder 1987, Zedler 1987c).

Another effect of the digging treatment was to reduce the total number of days pool bottoms were inundated, an effect which was more evident in the wetter than average rainfall year of 1987/88, than in the very dry year of 1988/89. Fluctuation in water level was greatest in recontoured pools in the wet year, when they drained more rapidly than untreated pools. However, in the dry year this meant they rarely accumulated standing water. Therefore, pools more likely to retain water, had long periods of standing water during the wet year, but fluctuating water levels in the dry year. The effects of fluctuating water levels have not been clearly demonstrated, but some pool species (Anagallis minimus, Juncus bufonius, and Lythrum hyssopifolia) are most abundant just within pool margins where water levels fluctuate the most (Bauder 1987). In any case, they are strongly associated with micro-habitats which are intermediate in number of days inundated (Bauder 1987).

Statistically significant differences between seeding and digging treatments were not evident, with the exception of the positive effect of seeding on frequency of Pogogyne. The lack of significance can be partly attributed to the limited replication and disparity in response between replicates. However, some trends were evident. In both years, seeded pools had a greater number of pool species than unseeded pools. There is a suggestion that digging had a positive effect on the frequency of Downingia and Lythrum. In the first year there was a negative effect of digging on frequency of the exotics Erodium and Hypochoeris, but this trend disappeared in the second year. There is no obvious explanation. It would have been predicted that the longer duration pools would have had fewer quadrats with these inundation intolerant exotics. Digging may have buried the copious seed stored on the soil surface.

In conclusion, the digging treatment made a significant difference in length of water retention, but this was not reflected in significant differences in the frequency of pool or non- pool species. The low precipitation in 1988/89 was apparently responsible for the increased frequency of four non-pool species, since effects of digging and seeding treatments were non-significant, and the interaction of digging and year was non-significant. Between year differences in frequency were the only significant differences.

Statistical tests indicate the between year differences in the frequencies of Pogogyne and Downingia were non-significant, but non-statistical analysis of plant distribution patterns strongly suggests that recontouring promotes year-to-year stability in the distribution and frequency of these populations. This may be one of the most important conclusions made possible by the second year of data collection. In addition, it also gave evidence that the positive effect of seeding on the frequency of Pogogyne was sustained through a second year despite the exceptionally low rainfall. LIkewise, the tendency for seeded pools to contain a greater number of pool species was evident in both years. Thus, both restoration treatments had beneficial impacts on pools degraded by vehicles, and a combination of seeding and recontouring promises a greater benefit for the pools than either treatment applied alone.

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