An Overview of 15 Years of Vernal Pool Restoration and Construction Activities in San Diego County, California

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Abstract. We review the status of five vernal pool creation and restoration projects in San Diego County that were prompted by efforts to mitigate for damage to or destruction of *Pogogyne abramsii* and *Eryngium aristulatum* ssp. *parishii* populations. The first project was begun in 1981 and the latest in 1992. Some degree of success, defined as persistence of significant populations of the target species, was obtained in all of the projects. After 4 to 15 years, the average condition of artificially constructed basins was distinguishable from that of natural basins for some features, but overall the evidence suggested a gradual convergence of the function and characteristics of artificial basins toward those of natural pools. We conclude that artificial basins can support populations of native species for considerable periods. It is less certain that artificial basins will remain suitable habitats in perpetuity. This uncertainty, plus the substantial aesthetic, scientific, and historic value of natural landscapes argues for giving the highest priority to the preservation of natural landscapes.

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Introduction

The listing of *Pogogyne abramsii* (Lamiaceae) under the Endangered Species Act was the impetus for a series of studies beginning in 1979 that has involved many students and collaborators. These projects have covered a broad range of topics, but here we report on some of our studies related to the restoration and creation of vernal pools.

Pool restoration and creation were of interest from the beginning of our involvement in vernal pools. Pool creation was seen as a way of reducing the costs of mitigation. Adding pools to areas already owned by agencies required to mitigate for loss of pools elsewhere was thought to be less costly than buying land with undisturbed pools. Later, the fact that there were few areas which contained pools left to be purchased added to the appeal of creation. In other cases, restoration was included as a management tool (Rieger, 1987).

For all the projects we describe here, the primary goal was the establishment of self-sustaining populations of the endangered San Diego Mesa Mint, *P. abramsii*, and more recently, the San Diego Button-Celery, *Eryngium aristulatum* ssp. *parishii* (Apiaceae). Therefore, success in these projects was assessed by both population sizes and persistence of *P. abramsii* and *E. aristulatum* ssp. *parishii*.

The five projects ranged from rehabilitation of damaged natural pools to construction of completely new pools in specific locations which had supported other vegetation types. The studies have involved both monitoring projects in which the initial modifications or construction was effected by other parties and monitoring projects which we planned, carried out and monitored. Thus the methods for the various projects varied.

Vernal pool creation and the use of restoration as mitigation are controversial subjects. We have never been advocates for either practice. Our purpose has been to obtain information about the success of the projects and as objectively as possible to provide a basis for judging the utility of creation and restoration.

The Miramar Road EPA Pools

Introduction

The Miramar Road EPA pool project (named after the location and the Environmental Protection Agency suit which resulted in the study) involved rehabilitation of a series of natural pools where natural vegetation was cleared and surfaces were disked in March 1980. The natural vegetation was removed from the site and topographical features supporting vernal pools were largely destroyed. As a condition of the consent decree which settled a complaint brought by the U.S. Attorney under Sec. 301 of the Clean Water Act (United States of America v. Eastgate Miramar Associates), the site was fenced and our activities initiated.

The goals of the study were twofold: 1) to monitor the responses to disturbance and the recovery processes of highly disturbed pools; and 2) to facilitate the recovery of some pools by experimental manipulations aimed at restoring some of them to a state approximating the undisturbed condition. This study was primarily the work of Carla Scheidlinger and Cameron Patterson (Scheidlinger et al., 1987).

Methods

In May 1981 vernal pool vegetation and the locations of standing water in the 1980-81 rainfall season were mapped in 5 x 5 m quadrats forming a grid over the site. The site was divided into four roughly equal portions, and three separate basins were excavated in each of two of these sections, with basins centered on areas that had evidence of standing water. Three separate areas in each of the remaining two regions were identified as sites for observation and the recovery of disturbed pools. Inoculum in the form of plant litter and the top 1-2 mm of soil salvaged from a natural vernal pool area adjacent to this site scheduled for development was placed in three excavated basins and three unmodified disturbed areas. This inoculum contained seeds and propagules of vernal pool plant species and eggs and resting structures of vernal pool fauna. We established a 2 x 2 factorial design, with the factors 'reconstructed/not reconstructed' and 'inoculated/not inoculated'. Because of practical constraints, this design was pseudo-replicated because of the spatial association of the treatments. The results therefore must be viewed cautiously. Additionally, three relatively undisturbed pools from a small preserve approximately 100 m from the treatment area were investigated.

Initial results of the study are reported by Scheidlinger et al. (1987) and are presented briefly here. In preparation for this paper we inspected the pools and disturbed areas in April 1996. We recorded all vernal pool plant species (plants which in moderately wet years do not survive to the seed production stage outside of pool basins) we could observe during a 15-20 minute search period by two experienced vernal pool restoration specialists. Low standing biomass and plant densities in Southern California pools make it likely that few plant species which survived to maturity were missed during these searches. Total numbers of the relatively large and prominent individuals of *Pogogyne abramsii* and *Eryngium aristulatum* ssp. *parishii*, two endangered plant species which occurred in these pools were counted (for pools with less than 100 individuals) or estimated (for pools with greater numbers of plants) by counting individuals in representative sections of pools and extrapolating numbers to the entire pool. Pool areas were measured with a meter tape.

Results and discussion

There was a significant positive relationship between maximum pool depth and total days of standing water for the pools at the Miramar Rd. EPA site, 1981-82 through 1983-84 (Figure 1). Restructured pools held water significantly longer at given maximum water depths than did non-restructured pools (Figure 1).

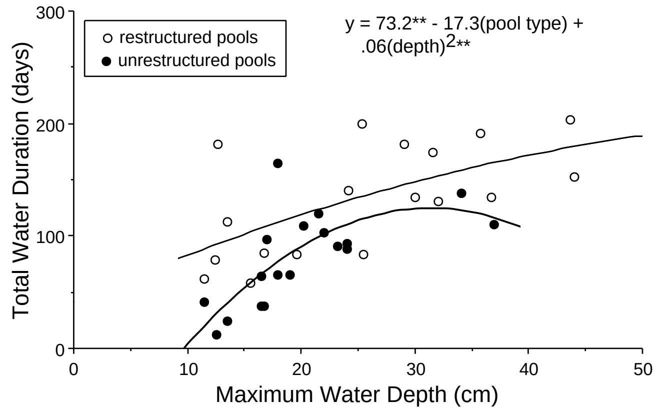

FIGURE 1. Maximum depth-total water duration relationships for restructured and non-restructured pools on the EPA site, 1982-1984 (** indicates factor significant at the p < .01 level; * indicates factor significant at the p < .05 level, no * indicates factor not significant at the p < .05 level; separate curves presented for the two pool types).

Although we did not record water levels in the pools during the 1995-96 season, it was evident that several of these pools had not held water this dry year. Some aquatic plant species were not found in pools where they would be obvious in wetter years. We observed between six and 18 pool species in the various pools. The average number of pool species in the reshaped inoculated pools was slightly lower than in the three natural undisturbed pools (Figure 2). The reshaped non-inoculated pools averaged fewer pool species than the highly disturbed pools which were inoculated but not reshaped, but these reshaped non-inoculated pools were obviously dryer this season than the disturbed inoculated pools. The pools that were both reshaped and inoculated averaged both higher numbers and higher densities of *Pogogyne abramsii* compared with the other pools that had received less intervention (Figure 3). Values were not as high, however, as those in the natural undisturbed pools nearby (Figure 3). The numbers of pool species found in the different pools showed a significant positive correlation with numbers of *P. abramsii* estimated in these pools (Figure 4). Numbers and densities of *Eryngium aristulatum* ssp. *parishii* were higher in the reshaped and inoculated pools than in the other pools on the site (Figure 5). There were no *E. aristulatum* ssp. *parishii* individuals present in the small preserve which contained the three undisturbed pools. The modifications to the hydrological characteristics of these relatively undisturbed natural pools which may have resulted from construction and development of the adjacent areas possibly caused this species to disappear.

Because pool vegetation was present on much of the site before treatments were implemented and because pool species readily invade uninoculated pools with time (see below), the "non-inoculated" factor probably has less influence on numbers of pool species present in these pools at this time than do water holding

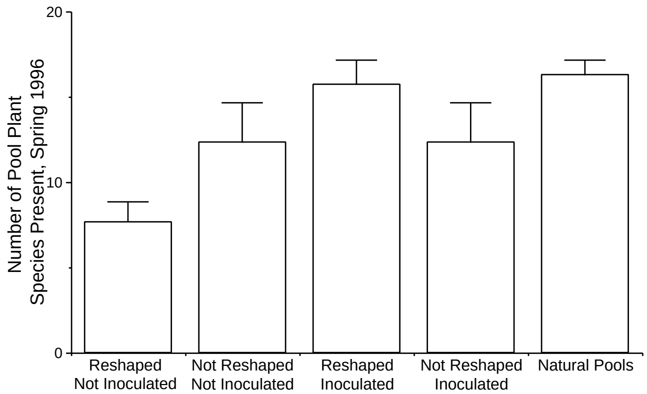

Figure 2. Numbers of pool species present in different treatments of EPA study pools (means of 3 pools ± 1 sem), 1996.

characteristics. Highly disturbed pools can hold water and support a consistent complement of pool species, but ruts remain in pools for decades, and sharp topographical gradients prevent the expansion of pool species with specific requirements and tolerances of inundation. The restructured pools on this site presented a much more "natural" appearance than did the disturbed pools, with broad bands of plant species corresponding to water duration zones. Based on the total numbers of pool species present and on the persistence and population sizes of

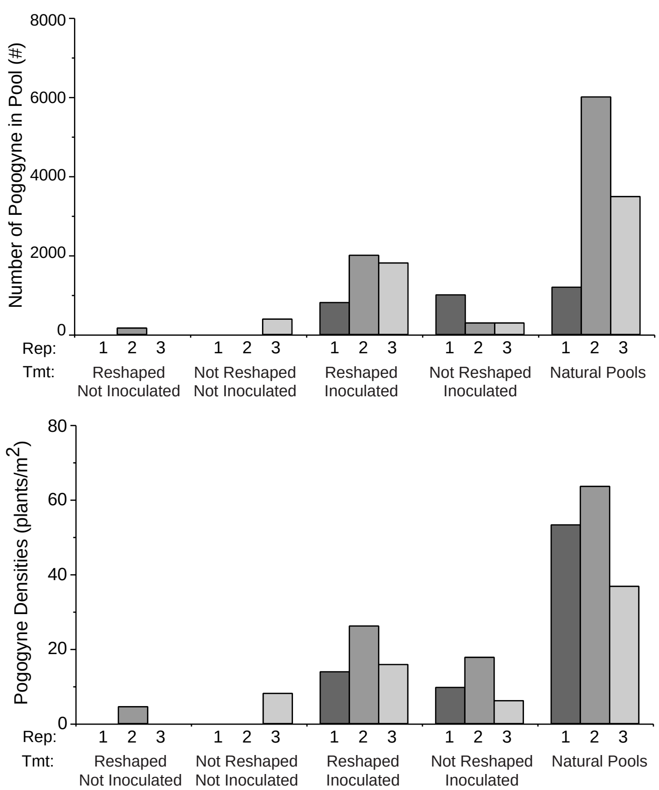

Figure 3. Numbers and densities of *Pogogyne abramsii* in 15 EPA study pools, 1996 (tmt = treatment, rep = replicate).

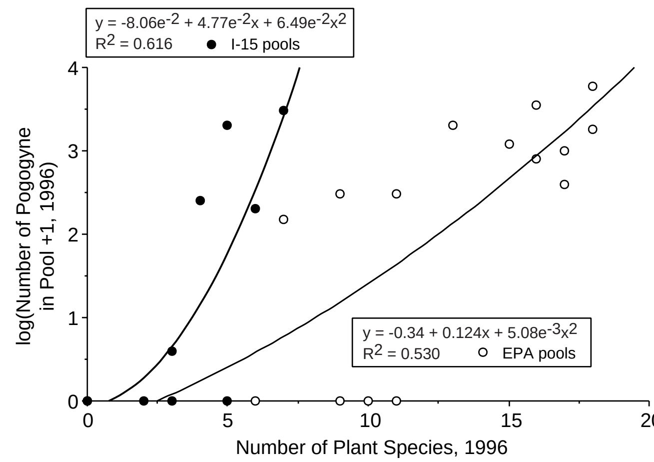

Figure 4. Numbers of vernal pool plant species and numbers of *Pogogyne abramsii* present in individual EPA and Caltrans I-15 pools, 1996 (linear and quadratic factors in equations significant at the $p < .05$ level).

two endangered pool species, the restructuring and inoculation treatment (which represents the most intensive of the treatments) was successful in restoring the pools, although the degree to which they resembled the original pools on the site is unknown.

Endangered species have persisted for 15 years after disturbance to this tiny preserve (approximately one-third hectare) which is effectively isolated from other pool areas by fencing, industrial development, and a wide busy road. A potentially detrimental effect of the small preserve size includes restricted gene flow of the species contained herein. A ground-squirrel colony and several rabbits in the preserve result in intense herbivory on some plant species: the aboveground portions of many *E. aristulatum* ssp. *parishii* individuals were largely eaten by late spring, 1996.

I-15 Caltrans Pools

Introduction and Methods

In 1985 John Rieger of Caltrans oversaw a project in which 10 shallow basins were excavated in the right of way of I-15 in San Diego, near the State Highway-163 merge. A number of natural pools are present within several dozen meters of these artificially constructed pools. Eight of the 10 newly constructed pools were inoculated with pool plant propagules and pool surface soil salvaged from a nearby site. The pools were monitored for two years by Carla Scheidlinger. Pool water levels were recorded in the 1985-86 and 1986-87 hydrological years by measuring pool water depths immediately after storm events and every 3-4 days thereafter until pools were dry. Pool species present in each basin were noted as above in 1985, 1986, 1987,

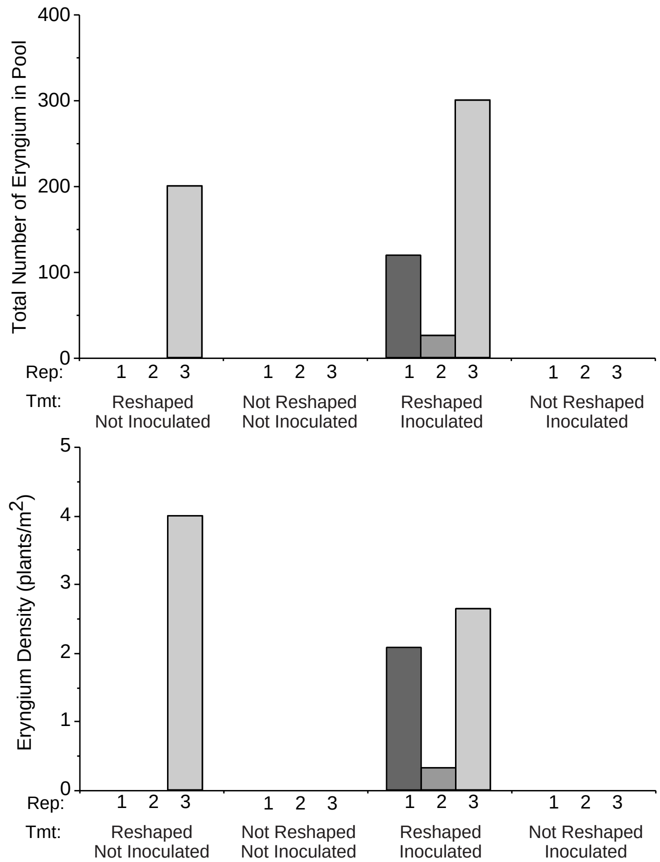

FIGURE 5. Numbers and densities of *Eryngium aristulatum* ssp. *parishii* in EPA study pools, 1996 (natural pools did not contain *Eryngium*; tmt = treatment, rep = replicate).

and 1996. We estimated numbers of *Pogogyne abramsii* in each basin as above where this species was present in spring 1996.

Results and discussion

The pools showed a wide variety of water regimes. Two pools were dry, not holding water in 1986-87 and probably not in 1995-96. Another pool was extremely wet, receiving water from a pipe draining the adjacent freeway. Numbers of pool species in these pools in 1996 were 0, 0, and 3, respectively. *Pogogyne abramsii* was present in five of eight originally inoculated pools in 1996, although in the very wet Pool 4 the population consisted of only three individuals. As we found in the EPA Miramar Road pools, there was a significant correlation between numbers of *P. abramsii* and numbers of pool species (Figure 4), although the relationship was unique for each set of pools. *Eryngium aristulatum* ssp. *parishii* did not occur on this site, although large populations of this species occur in pools less than 1 km from this location. This project has been successful, so far, in increasing the regional population of *P. abramsii*, but in view of the apparent extirpations of this species at the site, the prospects for long-term success are questionable.

DEL MAR MESA CALTRANS AND MIRAMAR ROAD NAVY ARTIFICIAL POOLS

Introduction

We have been involved in large vernal pool creation projects at two different sites, one for the California Department of Transportation (Caltrans) and one for the U.S. Navy. Although these projects were initiated at different times and in different sites, there were common factors involving the construction of the groups of pools and we have been studying them with the same methods, so the results of the studies of these pools are reported together.

Del Mar Mesa Caltrans Pools

In late fall 1986, 40 artificial basins were constructed on Del Mar Mesa by a private contractor under the direction of Caltrans personnel. Thirty-seven of these were seeded with inoculum collected by hand collecting individual plants, and raking, shoveling and vacuuming meter wide transects through nearby natural pools in an attempt to induce the development of vegetation assemblages similar to those occurring in natural vernal pools. Poor success in supporting vernal pool vegetation by some of these pools led us to modify and combine some pools and to construct several new pools. In the initial pool construction, basins were excavated in the existing soil grade and excess soil was removed from the site. In subsequent construction activity surface soil was stockpiled, basins were excavated, and surface soils were spread back over the excavated basins. The project is intended to mitigate the loss of individuals of the endangered *Pogogyne abramsii* caused by extension of State Road 52. During the course of this project *Eryngium aristulatum* ssp. *parishii* was placed on the Federal endangered species list.

Water-holding characteristics of pools were determined by recording pool water depths immediately after storm events and every 3-4 days thereafter until pools were dry. Plant species present in each pool were recorded at 1-2 month intervals from initial pool wetting until vegetation was dry by 15-20 minute searches by experienced vernal pool researchers at times when various species were blooming or at peak vegetative development.

In late spring, when we could sample vegetation with minimal impact on pools, we recorded cover and plant species presence in l dm^2 quadrats at regular intervals along permanent transects running from pool margin to pool margin through pool centers. Cover was measured by examining 10 cm x 10 cm quadrats with a point-frame sampler with a double thread layer forming a grid with intersecting points at equidistant intervals. At each of the 25 nodes of the grid we recorded underlying cover type: vegetation, plant litter, rock, or bare ground. Plant standing biomass was measured by harvesting all aboveground plant biom-

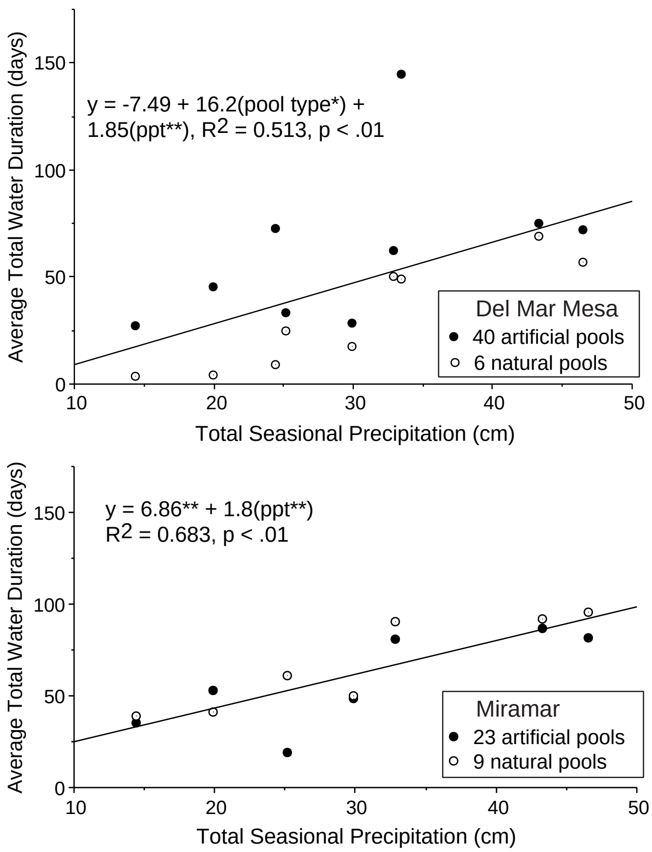

Figure 6. Seasonal total precipitation and total days standing water averaged by pool type (natural or artificial). Upper graph is for Del Mar Mesa pools 1986-87 to 1994-95 and lower graph is for Miramar pools 1989-90 to 1994-95 (no * indicates factor not significant at p < .05 level).

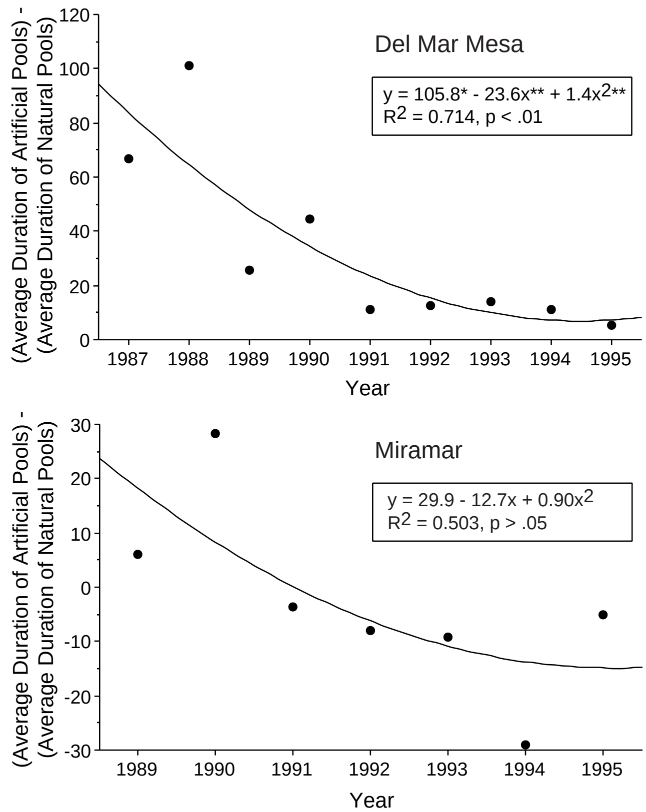

Figure 7. The difference in average total days standing water for artificial and natural (series 290 for Miramar) pools. Upper graph is for Del Mar Mesa pools 1986-87 to 1994-95 and lower graph is for Miramar pools 1989-90 to 1994-95 (** factor significant at the p < .01 level; * factor significant at the p < .05 level, no * indicates factor not significant at the p < .05 level).

ass in five randomly located 20 x 20 cm quadrats in 4-5 natural and 4-5 artificial pools at each site.

Pools were surveyed for numbers of *Pogogyne* by two different methods: 1) in early summer, when this species was at peak bloom and most conspicuous, we made a cursory visual survey in which we quickly counted numbers of plants in pools with low total numbers (i.e. less than 50), and estimated numbers of plants in pools with larger populations; and 2) later in the summer, after plants had set seed, a subset of pools at each site was examined with population transect sampling. Three to 10 transects at one to four meter intervals were established by running lines perpendicular to a tape placed along the longest axis of each pool. All individual *Pogogyne* plants were counted in successive 1 x 1 dm quadrats along these transects. Depending on numbers of *Pogogyne* we expected to find along transects, we harvested all *Pogogyne* in every quadrat (in pools which had sparse populations) or a subsample of quadrats chosen to represent the range of elevation and plant densities (in pools which had dense populations), in order to sample the size and seed bearing characteristics of the plants. Population numbers of *Eryngium aristulatum* ssp. *parishii* were counted (in pools with fewer than 75 individuals) or estimated by counting plants in subsections of pools and extrapolating numbers to entire pool basins.

Miramar Road Navy Pools

Two experimental basins were excavated in the late summer of 1987 on Naval Air Station (NAS) Miramar. As was the case with the initial Del Mar Mesa artificial pools, the soil was simply removed to produce shallow pool-shaped excavations. The spoil was placed on a badly disturbed adjacent site. These pools were inoculated with plant propagules and surface soil scraped from nearby natural basins. Because these basins had reasonable water-holding characteristics compared with natural pools on the site, the following year we excavated twenty-three shallow basins in the same general area. For these basins, however, 10-20 cm of surface soil was scraped from the planned pool area and stockpiled, then 10-20 cm of subsurface soil was re-

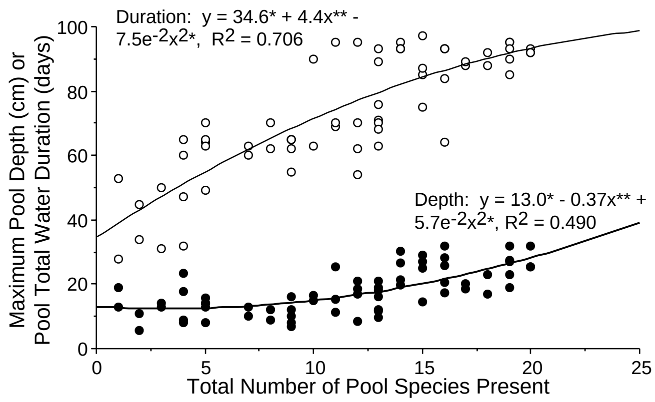

FIGURE 8. Number of pool species present in natural and artificial pools on different sites and pool maximum depths or maximum days standing water, 1994-95 rainfall season (** factor significant at the $p < .01$ level; * factor significant at the $p < .05$ level, no * indicates factor not significant at the $p < .05$ level).

moved from the site. The original surface soil was spread over the resulting hollow to produce pools possessing topography similar to natural pools on the site.

Water-holding characteristics, plant species present, and population numbers of *P. abramsii* and *E. aristulatum* ssp. *parishii* have been monitored in the artificial pools and in a set of eight reference natural pools on the site since 1989 with the same methods used on the Del Mar Mesa Caltrans pools.

Results

Pool water holding characteristics. Water durations (total days with any standing water) in the artificial and natural pools showed a positive correlation with seasonal precipitation totals (Figure 6). The artificial pools on both sites averaged greater water durations than the reference natural pools, but the average differences in duration between the artificial and the natural pools declined for the Del Mar Mesa pools from nearly 90 days at the beginning of the study to fewer than 10 days after nine years (Figure 7). The difference between the average standing water duration of the artificial pools and that of the natural pools (or that of the Miramar natural pools not influenced by road runoff, pools 290-293) also declined (Figure 7) to the point that the average duration of all the artificial pools was less than the average of the four most natural pools on the site. We believe that these changes correspond to the development of soil structure in the artificial pools resulting from plant growth and the development of cracks with repeated wetting and drying cycles.

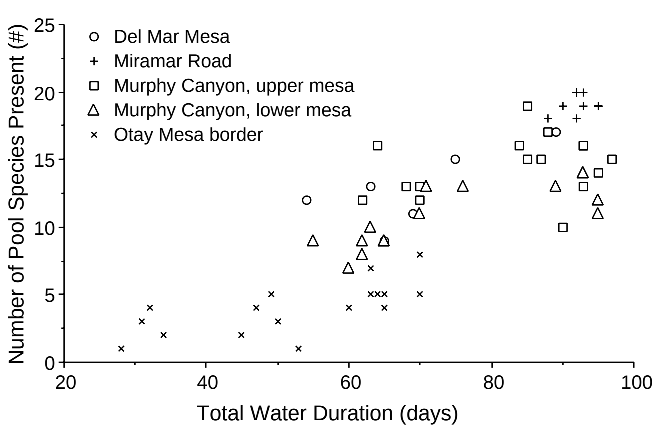

FIGURE 9. Numbers of pool species in natural pools in five different areas and pool total water durations, 1994-95 rainfall season.

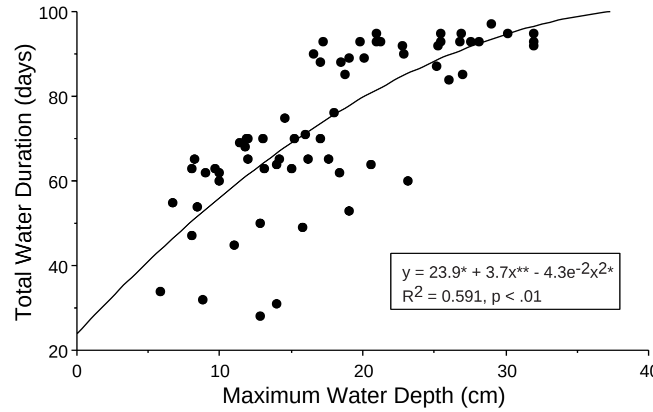

FIGURE 10. Maximum depth and total water duration for all natural pools in different areas, 1994-95 rainfall season (** factor significant at the $p < .01$ level; * factor significant at the $p < .05$ level, no * indicates factor not significant at the $p < .05$ level).

Pool species richness, plant cover, and biomass. The numbers of aquatic and semi-aquatic plant species found in natural pools showed positive correlations both with maximum pool depths and total water durations (Figure 8) with broad differences due to area (Figure 9). Although maximum water depth and total water duration showed a positive correlation (Figure 10) numbers of species present were more highly correlated with total days water duration (Figure 8). A partial correlation, in which number of pool species was correlated with either maximum pool depth or total water duration, statistically holding the other

TABLE 1. General linear model testing the factors of water duration (squared) and pool type (natural or artificial) against number of pool species present, 1994-95 rainfall season.

$r^2 = .6365$

Source of variation	df	Sum of Squares	F ratio	p > F
pool type	1	33.410	3.943	0.0493
water duration^2	2	1608.025	94.892	0.0000

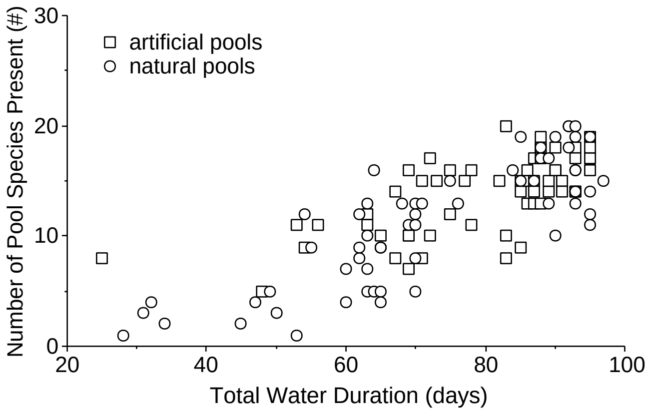

FIGURE 11. Water duration and number of pool species present in natural and artificial pools, 1994-95 rainfall season.

variable constant, resulted in a correlation coefficient (r) of 0.676 for water duration, but only of 0.078 for maximum water depth. Presumably, long water durations more effectively eliminated invading upland species than brief periods of deep water. Sixty artificial pools that we studied in 1994-95 had water duration-number of pool species relationships very similar to natural pools the same year (Figure 11, Table 1).

Numbers of pool species in natural and artificial pools at the Del Mar Mesa and Miramar sites showed positive correlations with seasonal precipitation totals (Figure 12). At Del Mar there was a significant effect of pool type, with artificial pools having fewer pool species at given precipitation levels than natural pools (Table 2), whereas at Miramar the effect of pool type was not significant (Table 3). In dry years, species can be expected to have both low germination and low survivorship so that some will be absent at the time of sampling.

Pool species colonization of uninoculated basins. At both sites three artificially constructed pools were left uninoculated and checked each year for presence of pool species. Numbers of pool species increased in these pools (Figure 13). There was a significant relationship between numbers of pool species and both total seasonal precipitation and numbers of pool species the previous year (Table 4) for these uninoculated pools. Some of the dispersal to uninoculated basins can be attributed to rabbits (Zedler and Black, 1992), but as the pools were visited frequently during monitoring, inadvertent human dispersal may also have played a role.

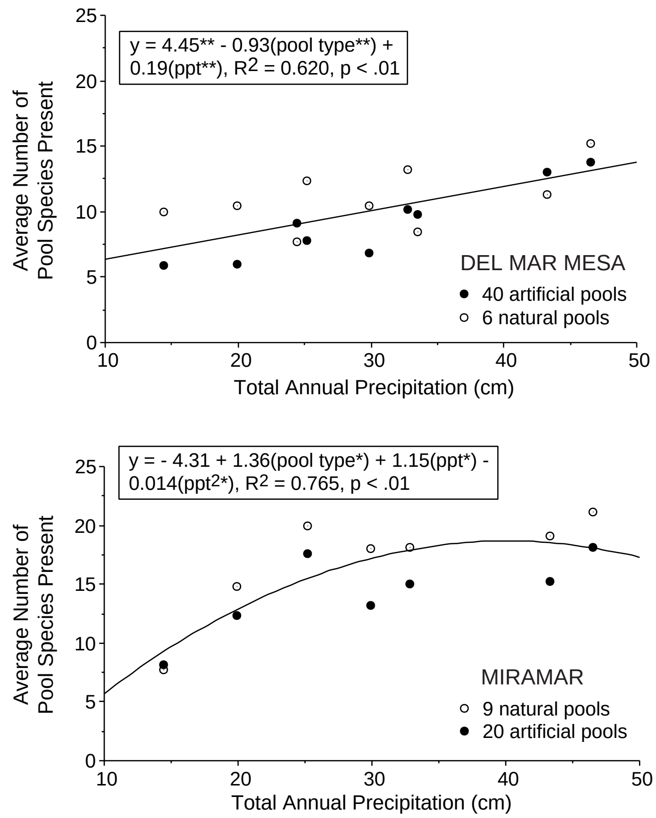

FIGURE 12. Numbers of pool species present in natural and artificial pools averaged by pool type. Upper graph is for Del Mar Mesa 1987-1995 and lower graph is for Miramar 1989-1995 (** indicates factor is significant at the $p < .01$ level; * indicates factor is significant at the $p < .05$ level, no * indicates factor not significant at the $p < .05$ level).

Vegetation cover and plant biomass. Plant cover measured by point frame sampling of vegetation quadrats along transects through a subsample of both pool types at both pool sites increased with seasonal precipitation (Figure 14), as did current year's plant biomass (Figure 15).

TABLE 2. General linear model testing pool type (natural or artificial), seasonal precipitation total, and their interactions against numbers of vernal pool species present in the Del Mar Mesa pools.

$r^2 = .620$

Source of variation	df	Sum of Squares	F ratio	p > F
pool type	1	15.5924	4.9549	0.0418
seasonal precipitation	1	61.5016	19.5439	0.0005

TABLE 3. General linear model testing pool type (natural or artificial), seasonal precipitation total, and their interactions against numbers of vernal pool species present in the Miramar pools.

$r^2 = .5375$

Source of variation	df	Sum of Squares	F ratio	p > F
pool type	1	26.0579	2.8267	0.1209
seasonal precipitation	1	91.7712	9.9550	0.0092

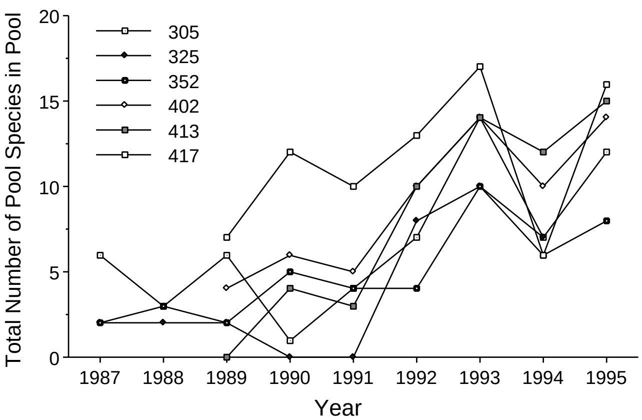

FIGURE 13. Numbers of pool species in non-inoculated pools at Del Mar Mesa (300 series pools) and Miramar (400 series pools).

Populations of rare species. Both these projects had as the primary objective the establishment of new populations of *Pogogyne abramsii*. Initial population sizes of this species in Del Mar artificial pools were moderate, declined during the drought years 1989-1991, and have increased during the past several years (Figure 16). At this site there is a significant relationship between seasonal precipitation totals and average artificial population size ($r^2 = 0.89$, $p < .01$, Figure 17). For the artificial pools at Miramar, which hold water for longer periods of time than the Del Mar artificial pools, there was no correlation between seasonal precipitation totals and *P. abramsii* populations in artificial pools ($r^2 = 0.20$, $p > .05$).

Several artificial pools (and one natural study pool) have had apparent extirpations of *P. abramsii* – that is years in which no individuals survived to flowering. We use the term “apparent extirpations” because other studies have shown that the seedbank of *P. abramsii* is persistent and that populations of this species can reappear after being absent for several years.

The proportion of artificial pools with apparent extirpations of *P. abramsii at* Del Mar is highly correlated with seasonal precipitation totals (Figure18). At Miramar a single inoculated pool has not supported this species to flowering in two dry years. At this site *P. abramsii* has appeared in two of three uninoculated

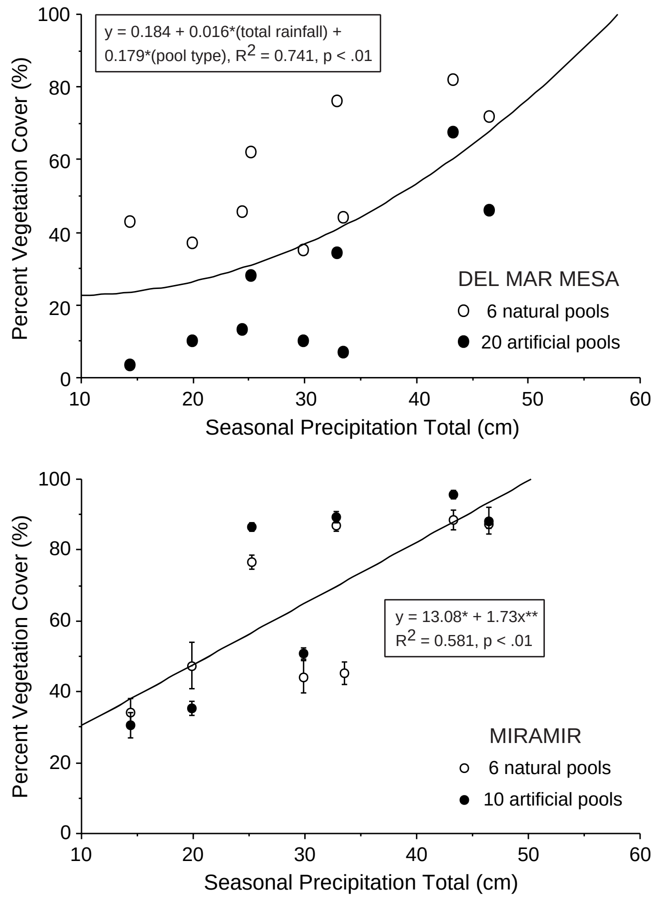

FIGURE 14. Percent vegetation cover averaged by pool type and total seasonal precipitation. Upper graph is 1987-1995 for Del Mar Mesa pools and lower graph is 1988-1995 for Miramar pools (** factor significant at the $p < .01$ level; * factor significant at the $p < .05$ level, no * indicates factor not significant at the $p < .05$ level).

pools, although it has not established consistent populations in these pools. In contrast, it did not invade any of the uninoculated pools at Del Mar, although it became well established in one pool one-to-two years after this part of the project was terminated and seeds of this species were placed in the pool. Although *P. abramsii* may apparently become extirpated in a pool, the seeds may remain viable in the soil for at least seven years, based on the results of an experiment we are conducting at the Miramar site.

TABLE 4. General linear model testing seasonal precipitation total and numbers of pool species in the previous year against numbers of vernal pool species present in Del Mar Mesa and Miramar uninoculated artificial pools (interaction term not significant).

$r^2 = .6129$

Source of variation	df	Sum of Squares	F ratio	p > F
seasonal precipitation	1	252.2890	27.7477	0.0000
previous year # species	1	164.2480	18.0646	0.0001

MURPHY CANYON POOLS

Introduction and Methods

In fall, 1992 we began studies on the water-holding characteristics and vegetation of pools and depressions on the upper mesa of the U. S. Navy Murphy Canyon vernal pool reserve site with the goal of evaluating them for their suitability for restoration or enhancement as habitat for *Pogogyne abramsii*. Natural pools

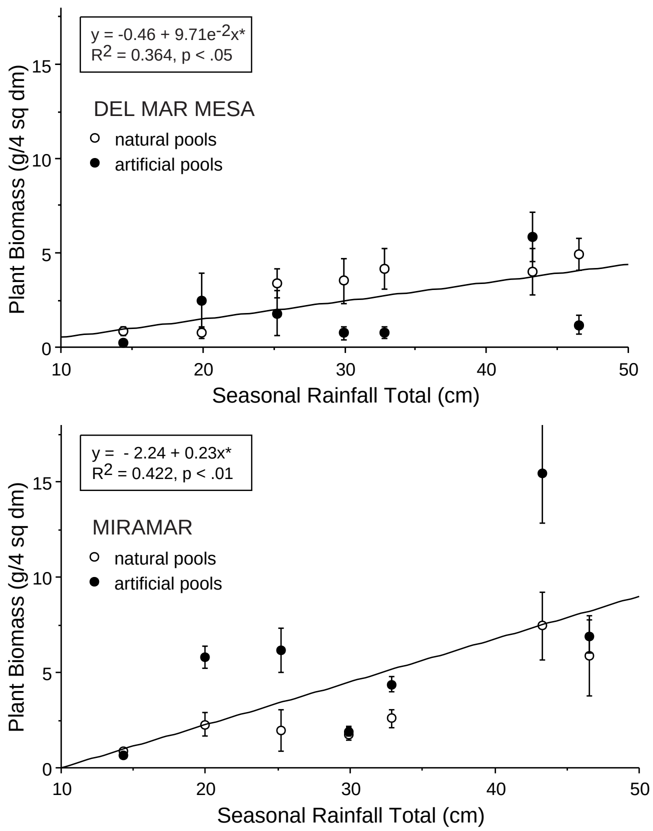

FIGURE 15. Standing biomass in unfenced pool sampling quadrats averaged by pool type and year, and total seasonal precipitation. Upper graph is Del Mar Mesa, 1989- 1995, and lower graph is Miramar, 1989-1995 (mean ± 1 sem).

on the site support healthy populations of this species despite past abusive land uses. Several of the pools had served as dump sites for domestic refuse in the recent past, and others had been impacted by construction equipment. After one year of study we smoothed ruts, slightly deepened, or removed trash from seven pools on the site and added a berm to the lower edge of one large pool. *Pogogyne abramsii* seeds collected from pools on the site were added to six of the pools that had previously not supported *P. abramsii* and to one pool that had contained only five plants in the initial year of study. Pool water holding characteristics and vegetation properties were measured as above.

Results

The average size of *Pogogyne abramsii* populations in the existing pools on this site showed a positive correlation with total seasonal rainfall (Figure 19) and function appeared was similar to that of the Del Mar artificial pools. The percentage of natural pools with apparent *P. abramsii* extirpations showed a negative correlation with increasing seasonal precipitation totals, again similar to the function for the Del Mar artificial pools (Figure

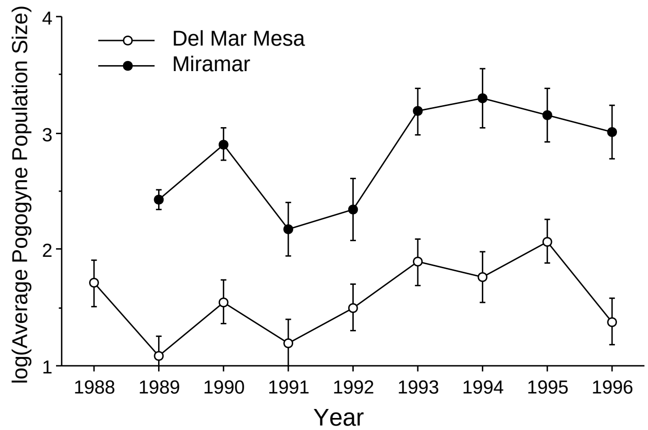

FIGURE 16. Average *Pogogyne abramsii* populations in artificial pools at Del Mar Mesa and Miramar (mean ± 1 sem).

18). A larger proportion of the Murphy Canyon natural pools had no individuals of *P. abramsii* surviving at given precipitation levels, however. This species became established in the modified and inoculated pools the first year after they were deepened and inoculated (Figure 20). Each of the three years since establishment in these pools, the average population number was greater than in the set of natural pools in which *P. abramsii* was found.

CONCLUSIONS – WHAT HAS BEEN LEARNED?

Can "Success" be Claimed?

It is the nature of endangered species management that project "success" for creation and restoration has come to be narrowly defined and almost as much a matter for lawyers as for biologists. This discussion therefore requires a disclaimer: we offer no opinion of whether or not any of the projects has met the stipulations of the U. S. Fish and Wildlife Service, the California Department of Fish and Game, or other regulatory agencies involved. In a general biological sense, success of species is mostly a matter of persistence. If a reserve still has the target species present after a period of time has passed, something that could reasonably be called success has been achieved – but only up to that point. By that very lax standard, all of the project areas have been "successes" for *Pogogyne abramsii*. That is, we have shown that *P. abramsii* will persist for at least 5-10 years in artificially constructed and restored basins.

With hindsight, this does not seem surprising. Prior to the implementation of more stringent control of access, many vernal pool areas in San Diego County were subject to vehicle disturbance. It is not uncommon for *P. abramsii* to establish populations in what are clearly either severely disturbed portions of natural pools or road ruts created by vehicles when the soils were saturated. This would not be expected if there was some specific

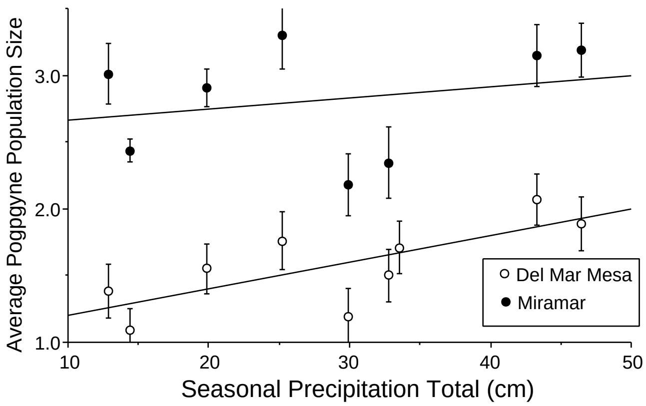

FIGURE 17. Average *Pogogyne abramsii* population sizes in artificial pools at Del Mar Mesa (1987-1996) and Miramar (1989-1996) and seasonal precipitation totals. (Del Mar Mesa model $R^2 = 0.888$, $p < .01$; Miramar model, $R^2 = 0.197$, $p > .05$).

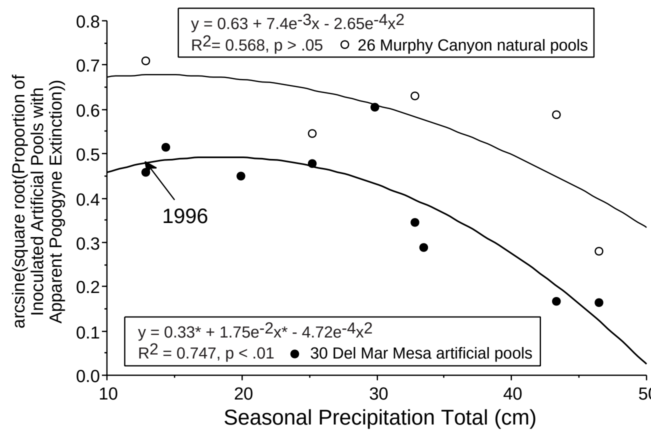

FIGURE 18. Proportion of Del Mar Mesa inoculated artificial pools and Murphy Canyon natural pools with apparent *Pogogyne abramsii* extinction and seasonal precipitation totals (** factor significant at the $p < .01$ level; * factor significant at the $p < .05$ level, no * indicates factor not significant at the $p < .05$ level).

quality of natural pool basins that is required by *P. abramsii* and other vernal pool plants.

But it is important to note that these ruts and all of the artificially constructed and restored pools discussed in this paper are located adjacent to natural pools. We know of no instance where *P. abramsii* has colonized constructed basins removed from natural pools, and its ability to survive in artificially constructed wetlands outside of historical vernal pool areas is questionable. If reasonable success for the establishment of *P. abramsii* can only be assured when pools are constructed among or near existing pools, the utility of pool creation as a mitigation measure is seriously in doubt. The main purpose of pool creation would then be to increase the proportion of the landscape that is vernal pool basin, thereby potentially increasing the total population size of *P. abramsii*. Although this is a theoretical possibility, it raises questions about trading off one habitat type for another and whether larger population sizes in small areas necessarily result in decreased probability of extinction of the endangered species (Zedler et al., 1993).

The capacity of *P. abramsii* and other vernal pool plants to survive in newly constructed pools is perhaps also to be expected because of their evolutionary history. A species that is specialized both for shallow inundated habitats and also for very particular soil conditions is not well suited to the continuously changing conditions of the California landscape in the last millions of years. Dependence on continued presence of a soil/topography/hydrology association would seem highly risky. Rather, one would expect the vernal pool flora would be specialized primarily for temporary inundation, and only secondarily if at all for particular substrates. This may explain why the novel conditions of artificial basins pose no great impediment to vernal pool species. If the hydrology is appropriate, the native vernal pool flora is capable of occupying it. This does not mean, of course, that the result is a pool indistinguishable from natural pools.

Should Vernal Pool Creation and Restoration be Encouraged?

Habitat creation remains a controversial subject. Our results have something to offer both sides of the debate, but we continue to advise that habitat creation not be relied on to offset losses of natural habitats. On the positive side, we have shown that it is possible to create new vernal pool basins and to have populations of vernal pool plants, including endangered species, persist for more than a decade. In some cases, this has lead to artificial pools that are statistically and in some cases visually indistinguishable from natural habitat. On the negative side, we can offer no assurance that the degree of success achieved to this point will persist into the future. We have also shown that in at least some pools the hydrology is changing to become more like natural pools, but without detailed knowledge of the causes of this change, it is not possible to extrapolate this trend with confidence.

No data are necessary to identify one serious negative of habitat creation – the loss of information that occurs when a natural habitat is destroyed. The unique history and properties of a natural habitat cannot be simulated. A natural system like a vernal pool may be compared to a valued historical building, the California state capitol , for example. At any moment, they both provide habitats for organisms – people or *Pogogyne abramsii* – but they have a meaning and value beyond their current utilitarian purposes. Both have aesthetic value, and even to those who perceive no beauty they have historical significance. But unlike a building, a vernal pool landscape stretches back for

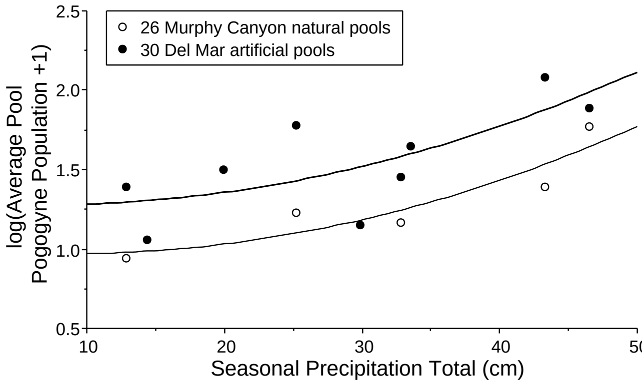

FIGURE 19. Seasonal precipitation totals and average *Pogogyne abramsii* population sizes for Murphy Canyon natural pools and Del Mar artificial pools.

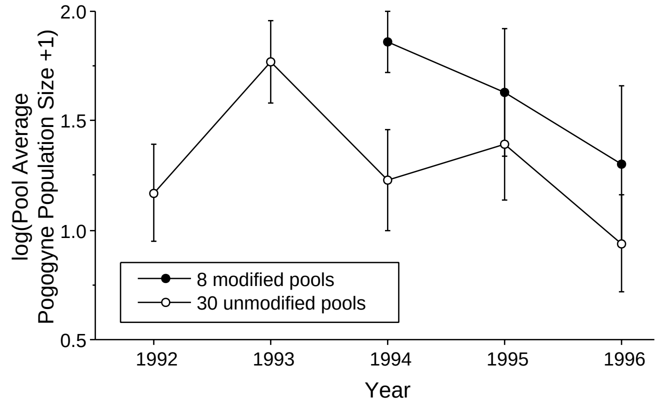

FIGURE 20. Average *Pogogyne abramsii* population numbers in unmodified pools and modified and inoculated pools (means ± 1 sem).

thousands to millions of years, and this immense history is recorded in the soils, topography, and genetic structure of the resident populations. This information can be read by the methods of science. A careless destruction of such historical repositories is a loss of information. It is difficult to put a price on this loss, but we can say that it cannot be compensated for by the creation of new habitats.

This is not to say that creation of artificial habitats should never be considered. At the very least, they can buy time as temporary habitats for vernal pool organisms, and this function may be of use when the destruction of natural vernal pools is a certainty. In such a case, the creation of artificial pools does offer partial mitigation. We caution, however, that the disturbance to the area in which the vernal pools are to be constructed must also be considered (Zedler et al., 1993). A worst case would be disrupting one valuable natural biotic community, such as coastal sage scrub, to "save" another. This could only be justified by carefully considering the condition of each community and whether the proposed creation project would lead to the preservation of additional natural areas or only disturb one already assured protection.

Restoration of vernal pools is perhaps a less controversial subject, though depending on the circumstances we are not sure that it should be. A weaker form of the arguments made above apply as well to restored habitats. There is no assurance of success, and restored pools, unless restored from only minor disturbance, do not have the same historic and scientific interest as undisturbed pools. There is no way to mitigate for the loss of historical information or historical context. We therefore also caution restraint in seeing restoration as an acceptable mitigation for the loss of high quality (little disturbed) vernal pools.

We believe that both habitat creation and habitat restoration have a role to play in conserving natural communities, but we are concerned that they be utilized in appropriate situations. Preservation of high quality natural habitat in sufficiently large and well-managed reserves must remain the primary objective of conservation efforts.

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