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Techniques for Mitigating Loss of Vernal Pools- An Experimental Approach

Undertaken for the California Department of Transportation

by

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April 15, 1998

Techniques for Mitigating Loss of Vernal Pools- An Experimental Approach

A technical report prepared for the

CALIFORNIA DEPARTMENT OF TRANSPORTATION
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16. Abstract

We inoculated 3 sets of 5 artificial vernal pools using materials from natural pools. We obtained inoculum from source pools by three methods (scraping/vacuuming, removing blocks of pool bottom, and removing loosened soil) and transferred it to created pools. From 1993-96, we sampled plants and invertebrates in all pools, which were fenced.

Soil-transfer produced greater diversity and relative cover of native wetland plants than other techniques, but all created pools outperformed natural pools in these criteria. Success of invertebrates in created pools was less than for plants, and highest in the soil-inoculated pools. Inhabitants of the water-column did better than benthic forms.

We analyzed the effect of inoculum-removal on source pools with three treatments: leaving scrape/vacuum plots alone, leaving the excavations from which pulverized soil was taken, and filling the depressions from which blocks were taken with clean upland soil. With fencing, all source pools rapidly lost diversity, but loss was less on inoculum-removal plots. The scrape/vacuum and soil-fill techniques led to some invasion of pools by non-native species, but this did not occur in the excavations left after soil had been removed.

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DISCLOSURE STATEMENT

This report is the final report for contract number 65T343 between the State of California, Department of Transportation (Caltrans) and Sonoma State University which is part of the California State University System. The total amount of the contract was $203,097.

DISCLAIMER STATEMENT

The contents of this report reflect the views of the authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the STATE OF CALIFORNIA or the FEDERAL HIGHWAY ADMINISTRATION. This report does not constitute a standard specification or regulation.

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We are deeply indebted to many people who provided ideas, logistical support, technical information, labor, and many other kinds of help. Harold Hunt and Jeff Gidley of Caltrans were indispensable in selecting our study site, arranging for permission to use it, and providing assistance in helping us structure the project and bring it to fruition. Robert Holmes introduced us to Travis Air Force Base, provided fencing for our study areas, and helped us in many other ways. Janet W. Reid and Brenda Hann provided indispensable help by identifying microcrustaceans in our samples to species, and Larry Serpa shared his knowledge about vernal pool invertebrates. Mike Hearty artfully composed the maps for our final report. Several consultants shared their experiences with us early in our work, most notably Ken Whitney, Nancy Wymer, and the late Jim Jokerst. As we approached our final design, Ann Howald provided challenging questions to us that shaped our work significantly. Ward Hensill made several devices that we needed for transplanting materials and sampling. We were assisted in the field by Lynn Stafford, Mark Smith, Debbie Eakins, Elsie Northen, Peggy Rockwood, and Linda Esposito. Our sincere thanks go to all of these friends and colleagues.

Chapter 1-Concept, General Methods, Summary, and Implementation

INTRODUCTION

Vernal pool habitats in California contain unique floras and faunas, with a high degree of endemism (Holland 1976, Kerster 1976). This endemism alone has led to the existence of a number of rare vernal pool species. Because the low-lying habitats where vernal pools are found are also suitable for development, a number of these species have also been classified by state and federal agencies as threatened or potentially so. Highways, by their nature, must often cross vernal pool habitat zones. While considerable protection of habitats is possible by selection of routes of minimal impact, any route in these zones will transect a certain number of vernal pools. Attempts have been made to transplant vernal pools or to create artificial pools as mitigation for various developmental projects.

In a seminal paper, Ferrin and Gevirtz (1990) reviewed such attempts at restoration and creation, and asked in their title whether "restoration and creation" should follow "cookbook recipes or complex science." In the recipe approach, used in the majority of projects including work on the Del Sol reserve in Santa Barbara County (Ferrin and Pritchett 1988), one uses "excavation+seed+water" to get a vernal pool. Various measures of success are then applied to determine if the community has values of a vernal pool. These authors reported success for several projects, but indicated that the measures of success are divergent and that there is no general consensus about what "success" means. They therefore called for rigorous testing of several hypotheses: "Vernal pools can be restored or created (1) to resemble the physical and biological attributes of natural vernal pools, (2) to provide the functional values of natural vernal pools, and (3) to be self-sustaining ecosystems." They defined a "self-sustaining" pool as "one that supports natural values and does not require assistance (e.g. application of water, removal of invasive exotics, and transplantation of native organisms) to persist indefinitely."

One aspect of "complex science" in our interpretation is that a variety of studies are undertaken to understand the function of vernal pools, and that this knowledge is

considered to be prerequisite for restoration. Detailed descriptive studies of particular species and natural pools would be combined with experimental manipulation of such pools to determine in a comprehensive way how vernal pool ecosystems function. Once the science has reached a certain stage, precision in creating artificial vernal pool habitats will be possible. The more precise the goals of a restoration project, particularly one that intends to improve the quantity of habitat for a particular target species, the greater must be the scientific understanding of the issues. The "complex science" issue, however, presents a dilemma, one that is at the basis of much controversy in conservation biology: if we wait for our scientific understanding to be perfect before we do anything in ecosystem management, the resource may be gone before we act.

A second aspect we see in "complex science" is that in creation projects or experiments, rigorous testing of hypotheses with quantitative data would be undertaken. No single study or project can be expected to provide a complete understanding of the ecosystems involved, but such studies should be based on quantitative data that can provide clear answers to a limited set of questions. We took this approach, and asked:

1. Do created vernal pools supplied with a source of inoculum develop characteristics of natural pools? Do these characteristics appear to the same degree in comparable but uninoculated pools?

2. Does waiting through one wet season before inoculation, allowing a created pool to stabilize, improve its performance?

3. Which of three inoculation methods produces the best correspondence of created pools to the natural ones from which seed and/or soil was taken?

4. How do different methods of removing materials from natural pools for use in inoculation affect these natural pools?

In the process of answering these questions, we also developed thorough, quantitative descriptions of the plant and invertebrate animal communities of the natural and created pools that provide additional insights. Our experimental design is given below, and details of methods appear in individual chapters.

Prior to finalizing our design, one or more of us visited with several consultants involved with wetland restoration, including Sugnet and Assoc., LSA, Jones and Stokes, and Nancy Wymer. One member of our team visited the Del Sol site, and we interviewed Mike Long of U.S.F.W.S. who at the time was managing the monitoring of wetland projects for his agency. Susan Holve-Hensill of our team had done extensive vernal pool mitigation work on the PGT-PGE/Bechtel Pipeline Expansion Project in the Central Valley working with Prunuske

Chatham, Inc. Through these consultations, it became clear to us that a variety of means have been employed for inoculation of created pools, and that these may have different degrees of success that have not been explicitly evaluated.

In the most time-intensive method of inoculation, employed by Wymer in her 1989 transplant of a vernal pool on McClellan Air Force Base near Sacramento, the entire bottom of a pool was transferred as four inch thick blocks of rooted soil to the new depression. The work of Prunuske Chatham on the PGT-PGE/Bechtel Pipeline Expansion Project involved vacuuming and scraping seed and duff from natural pools to transfer elsewhere. Ferrin and Pritchett (1988) used a hand-scraping method to remove the top one cm of soil and organic material as inoculum from natural pools on Elwood Mesa in the Santa Barbara area. In other instances topsoil has been removed to a greater depth with heavy equipment and applied to created pools. Zentner (1989) used a combination of soil removal, vacuuming, mowing and hand picking on the Laguna Creek Vernal Pool Creation Program. He noted that mowing was ineffective in this particular project because of the uneven bottoms of source pools. Although he found hand-picking to be time-intensive, it was effective for certain targeted species.

The rough micro-topographic variation on pool bottoms in our study would have made mowing impractical. Some pool bottoms had very large clods of dirt from disking, while others had deep hoof prints from horses and cows. We did not consider hand-picking because we wanted to introduce resting stages of invertebrate animals as well as seed, and samples from other methods would include both seed and animal propagules from source pools. We therefore decided to mimic: (1) the vacuuming, shallow scraping technique of Prunuske Chatham; (2) the intact pool-bottom method of Wymer; and (3) and the soil removal technique of Zentner and others, which is also similar to that of Ferrin and Pritchett, but with soil removed to a greater depth.

Our experiments required that we create 15 artificial pools with equivalent properties of water depth and slope. Pools with bowl or elongated shapes, like those of most natural pools, would differ markedly from each other in their affect on plant species if the level of hydration were not very closely equivalent, and this would make replication of our experiment difficult. In addition, by their structure such pools offer less habitat of a given water depth toward their centers than closer to their edges. To avoid these potential problems, we created the pools as flat, inclined planes three meters wide by ten meters long that superficially resembled broad, shallow ditches, not natural pools. We anticipated that these pools would fill to different depths, and that we would use data from the portions of all of them where depths were equivalent.

By this design of pools, we certainly violate the concept of "resembling the physical attributes" of natural pools given by Ferrin and Gevertz. The importance of our study is that by standardizing the created pools and using specific experimental designs we have been able to produce a reliable statistical analysis with which to answer our questions.

EXPERIMENTAL DESIGN

Experiment One: Comparison Of Methods For Inoculating Created Pools

Concept and overview of methods. We proposed to Caltrans to use statistical testing of hypotheses so that the success or failure of the experiment in creating vernal pools could be evaluated objectively. We indicated in our proposal an interest in testing methods of pool creation and methods of inoculation. Once we had been selected for the contract and had examined a site on Travis Air Force Base proposed for the experiment by Caltrans personnel, it became evident that only one method of pool construction was feasible and necessary. The site included within it small, possibly non-natural wetlands, in the Altamont clay soil series. The soil has thick clay surface horizons that would form a natural barrier to infiltration of water in the wet season, hence simply constructing basins in this soil was selected as the construction method. After delineating wetlands that lay nearby, we created three sets of five created pools each in adjacent uplands.

We established a model for evaluation of inoculation techniques that would involve three different methods, and would be done using three natural pools as sources of inoculum for the three different sets of created pools. We used three inoculation techniques:

1. Scraping and vacuuming source materials from the surface of natural pools and laying it on the natural surface of the created pool: we termed this "scrape/vacuum" and abbreviate it "Vac."

2. Cutting blocks of natural "sod" from the source pools and setting these in shallow trenches on the bottom of the created pool. We refer to this technique as "Blocks."

3. Crushing soil on pool bottoms with a backhoe and placing a layer of it on the created pool bottoms, a technique we call "Soil."

We also left one created pool unmodified as a control. All inoculum was taken from source pools in the dry season in early fall. It was placed in created pools prior to significant rain, rolled with a hand roller, and covered with a row cover material ("Remay") until germination

had begun. We placed inoculum in a pattern that assured that each section of the source pools was represented in each depth zone of the created pools.

Early in the study, we became interested in whether or not a created pool would perform better if it were allowed to go through one wet season prior to inoculation. To evaluate this question, we created a fifth pool in each set, and inoculated it one year earlier than the others using the Vac technique. We called this method "Vac1" because it was done in the first year. "Vac2" was performed the second year along with Blocks and Soil. Fig. 1.1 is a schematic diagram of the physical layout of the experiment. Full details of the plant sampling methods appear in the methods section of Chapter 2 while methods for invertebrate animals are given in Chapter 4.

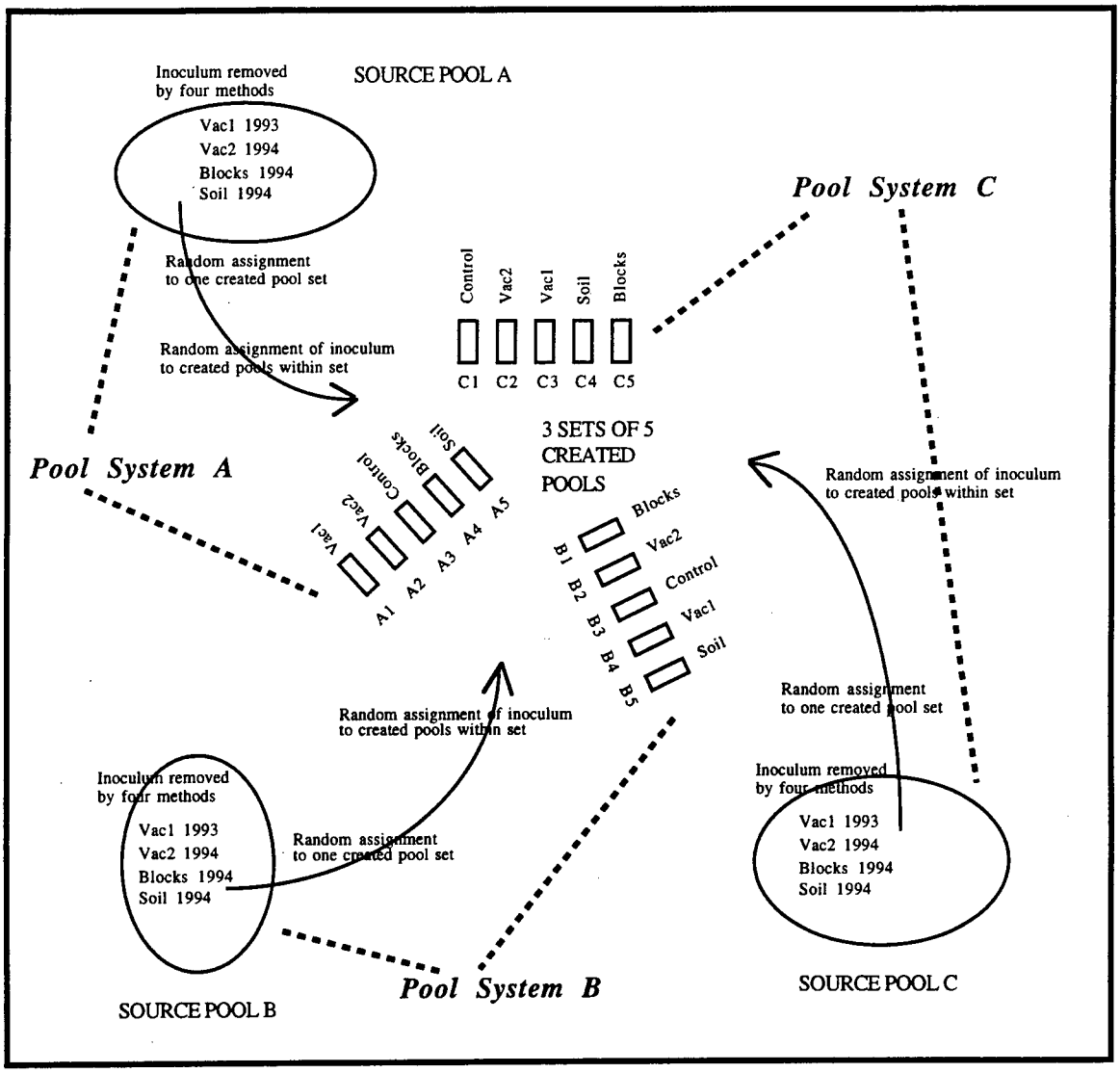


Figure 1.1 Conceptual diagram of the inoculation experiment.

Statistical models. We used a three-way analysis of variance model without replication to test how a number of responses of the pools dealing with success of native plants and of invertebrate animals were affected by the inoculation methods, pool systems, and years following inoculation. In this model, for a given response variable such as "plant species richness," each created pool and source pool generated a single value each year. "Treatment" in the statistical models refers to the inoculation methods as well as controls and source pools. In some tests, we examined inoculation methods alone to determine if they differed, while in others we examined methods plus controls or methods plus source pools. We did not test the set of all treatments (inoculated pools, controls, and sources) because the large differences between sources and controls would obscure any interpretation of the effect of the methods themselves.

For the question of how year of inoculation affected success, the model was:

2 treatments:	t=2	There were two methods (Vac1, Vac2).
3 systems:	s=3	The experiment was done with three systems of pools, A, B, and C.
2 years:	y=2	The experiment has yielded values in each of two years for each treatment and system.

Factor	Degrees of Freedom
Constant	1
Treatment	(t-1)=1
System	(s-1)=2
Year	(y-1)=1
Total	tsy-1=11
Error	11-5=6

Hypotheses: For a given response variable in the vernal pools, such as relative cover of native wetland plants, number of native wetland plants per sample, or number of invertebrate taxa per pool:

H_O: Mean values for the response variable are the same among the treatments.
H_A: Mean values for the response variable are not the same among the treatments.

H_O: Mean values for the response variable are the same among the pool systems.
H_A: Mean values for the response variable are not the same among the pool systems.

H_O: Mean values for the response variable are the same between years.
H_A: Mean values for the response variable are not the same between years.

For all hypotheses, reject H_O in favor of H_A if $p \leq .05$.

For the question of how three inoculation methods affected success, how the inoculated pools compared in performance to source pools and how the inoculated pools compared in performance to controls, the model was:

3 treatments:	t=3	There were three methods (Vac2, Blocks, Soil). Alternatively test values from these three methods with controls, or values from these three methods with sources, in which case there are 4 treatments (t=4) for each test.
3 systems:	s=3	The experiment was done with three systems of pools, A, B, and C.
2 years:	y=2	The experiment has yielded values in each of two years for each treatment and system.

Factor	Degrees of Freedom
Constant	1
Treatment	(t-1)=2
System	(s-1)=2
Year	(y-1)=1
Total	tsy-1=17
Error	17-5=12

Hypotheses: For a given response variable in the vernal pools, such as relative cover of native wetland plants, number of native wetland plants per sample, or number of invertebrate taxa per pool :

H_O: Mean values for the response variable are the same among the treatments.
H_A: Mean values for the response variable are not the same among the treatments.

H_O: Mean values for the response variable are the same among the pool systems.
H_A: Mean values for the response variable are not the same among the pool systems.

H_O: Mean values for the response variable are the same between years.
H_A: Mean values for the response variable are not the same between years.

For all hypotheses, reject H_O in favor of H_A if $p \leq .05$.

Experiment Two: Comparison Of How Different Methods Of Taking Inoculum Affect Source Pools Themselves

Concept of the experiment. In a site visit prior to approval of the inoculation experiment by the California Department of Fish and Game and the U.S. Fish and Wildlife Service, Ann Howald, representing C.D.F.G., raised the issue whether or not removing

materials from source pools might adversely affect these pools. Spurred by this concern, we decided to remove materials from marked plots in a systematic way so that the question could be answered. We agreed to use no more than ten percent of the bottom of each pool as inoculum. We planned to use four methods for inoculating created pools (Vac1, Vac2, Blocks and Soil), which would leave us in source pools with either vacuumed areas or depressions on the pool bottoms, and we decided that a square meter of pool bottom should be the maximum size for a removal plot. We also were interested to know if plots of different sizes would have different effects.

Given these ideas and constraints, we decided to use four different treatments for the removal plots in each source pool, and to use plots of .25, .5, and 1.0 m^2 within each. The total amount of pool bottom used was the same for each method, and the amount needed meant that we would need to replicate the removal methods eight times within each pool.
Within each of these eight zones in each source pool, we randomly assigned locations of these four methods and each of the three plot sizes within each method:

1. Scraping and vacuuming source materials in year 1 (1993), referred to as "SV1."
2. Scraping and vacuuming source materials in year 2 (1994), referred to as "SV2."
3. Leaving unmodified the depressions from which soil had been taken (to a depth of 15 cm), referred to as "excavation," abbreviated "Exc" and done in 1994.
4. Filling the depressions left behind by removal of blocks of pool bottom with soil taken from below the root zone of nearby uplands, referred to as "Fill" and also done in 1994.

We began taking data on the plant communities of the source pools along three reference transects in each pool in Spring of 1993. We located the collection zones adjacent to these transects. Fig. 1.2 shows a diagram of reference transects and collection zones in a source pool, and Fig. 1.3 depicts a typical reference transect photographically. Fig. 1.4 shows how collection plots were organized at random within one zone. Photographs of the three collection methods and how material was used to inoculated created pools appear in Figs. 1.5-1.7.

Full details of the sampling methods are given the methods section of Chapter 3. For this experiment, one sample along the reference transect within each zone was randomly selected to represent reference values (abbreviated "Ref") in the unmodified plant community. Removal plots were each sampled in the same way as the reference plot.

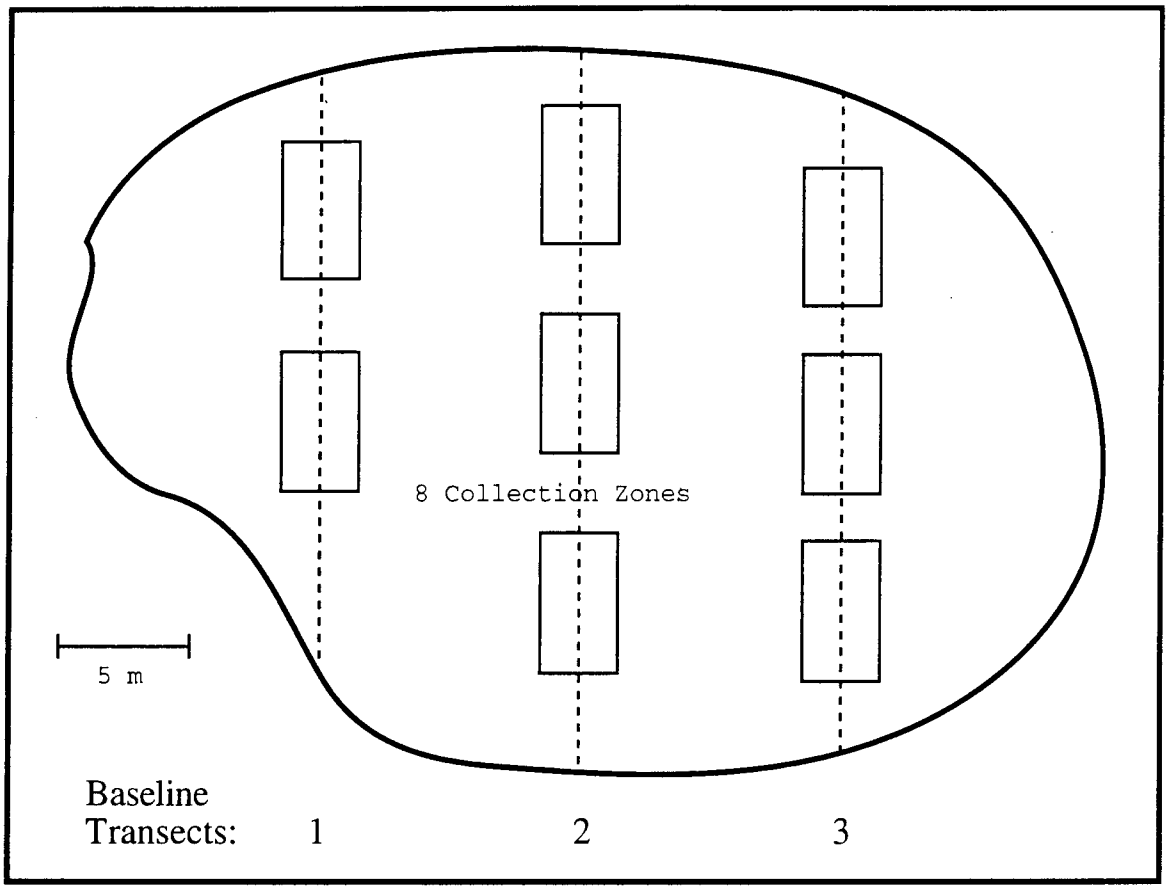


Figure 1.2. Diagram of sampling transects and collection zones along them in a hypothetical source pool.

Figure 1.3. Photograph of a reference transect in Fall, 1993, pool TR5. Orange stakes mark points were source materials were taken (collection not complete at the time of the photograph).

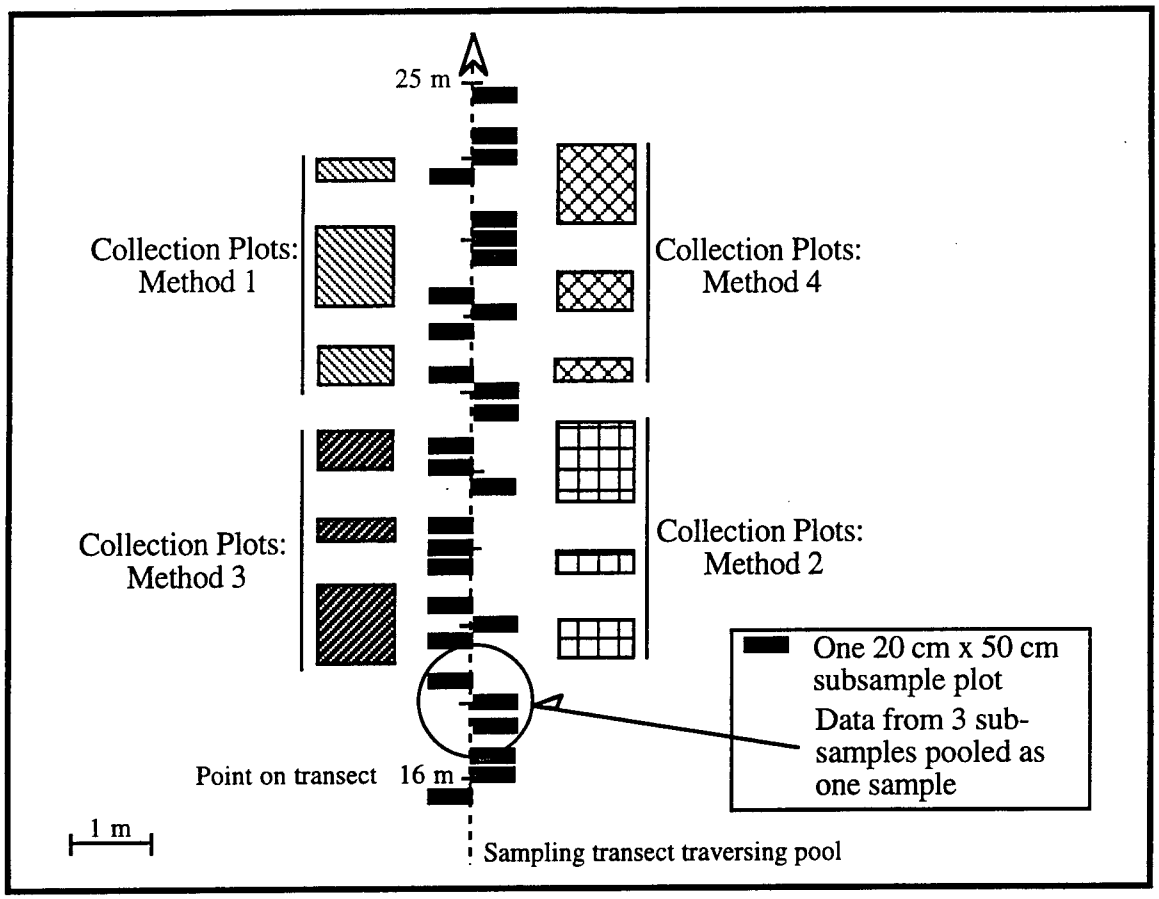


Figure 1.4. Diagram of sampling and collection plots within one zone along a segment of a baseline transect.

Statistical model. We used analysis of variance to test the effect of plot size separately within each method, and found that it did not have an effect (details in Chapter 3). We compared SV1 with SV2 with a number of quantitative measures also reported in Chapter 3, but did not apply analysis of variance. The main question of whether the removal methods and reference plots differed was tested with a three-way analysis of variance with eight replicates. We used this model to see if a given response variable in the plant community, such as relative cover of native wetland plants, was affected by "treatment" (the effect of SV2, Exc, Fill, and Ref), "system" (the source pools themselves-we kept the term "system" for consistency with the previous experiment even though created pools were not involved), and "year" (the changes in 1995, and 1996, the two years following the removal). The model also involved calculation of interaction terms among the three variables. We do not report these, but they were parts of the analyses.

For the question of how treatment of removal plots affected natural pools, the model was:

8 replicates (n=8) for each of: (In practice, one set had 7 replicates-see Chapter 3. This reduced total degrees of freedom from 191 to 183 because each of the four treatments had one fewer replicate in each of two years.)

4 treatments: t=4 Test each of three methods (SV2, Exc, Fill) and Ref

3 systems: s=3 The experiment is done with three systems of pools, A, B, and C.

2 years: y=2 The experiment has yielded values in each of two years for each method and system.

Factor	Degrees of Freedom
Constant	1
Treatment	(t-1)=3
System	(s-1)=2
Method*System	(m-1)(s-1)=6
Year	(y-1)=1
Treatment*Year	(t-1)(y-1)=3
System*Year	(s-1)(y-1)=2
Total	((n*t*s*y)-1)-8=183
Error	183-17=166

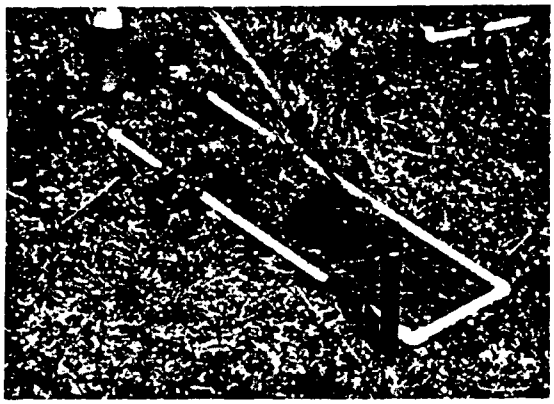
Hypotheses: For a given response variable in the vernal pools, such as relative cover of native wetland plants or number of native wetland plants per sample:

H_O: Mean values for the response variable are the same among the treatments.
H_A: Mean values for the response variable are not the same among treatments.

H_O: Mean values for the response variable are the same among the pool systems.
H_A: Mean values for the response variable are not the same among pool systems.

H_O: Mean values for the response variable are the same between years.
H_A: Mean values for the response variable are not the same between years.

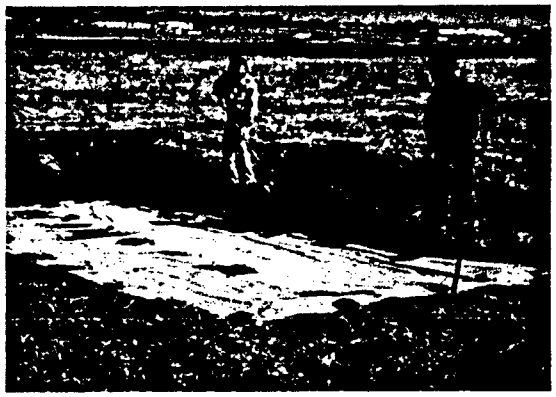
For all hypotheses, reject H_O in favor of H_A if $p \leq .05$.



Plants and duff removed by hoe

Remaining seed and loose soil vacuumed

Dry materials scattered in pool and rolled (see cover)



Inoculated pool covered before rains

Figure 1.5. Photographs of methods for removal of inoculum by the scrape/vacuum method and its placement in created pools.

Soil loosened by backhoe, crushed

Soil removed, excavations left as is

Removal from truck

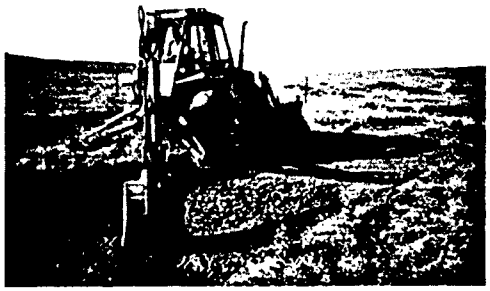
Piles from different zones later raked together, soil covered as shown in Fig. 1.5

Figure 1.6. Photographs of methods for removal of inoculum as crushed soil, leaving behind unfilled depressions, and the placement of soil in created pools.

Blocks scored and marked

Removal with shovel

Blocks transported on pallets



Trenches dug in
pool with backhoe

Finished pool

Figure 1.7. Photographs of methods for removal of inoculum as blocks of sod and its placement in created pools. Depressions left behind in source pools were filled with upland soil from below the root zone of nearby uplands (not shown.)

DESCRIPTION OF SOURCE AND CREATED POOLS

Jeff Gidley of Caltrans had arranged a potential site for the project on Travis Air Force Base in Fairfield with the assistance of Bob Holmes, base agronomist. It lies near the western boundary of Travis Air Force Base, southwest of the base hospital. The site slopes from an elevation of 90 ft on the west gradually down to 60 ft where it abuts a railroad track (Figs. 1.8 and 1.9).

Once we had agreed to use this site, we visited it with representatives from the California Department of Fish and Game to hear their concerns. Our final design for the project was approved by U.S.F.W.S. after a consultation we had with Jan Knight and Jamie King of that agency.

In late January of 1993, when all vernal pools of the Fairfield area were fully hydrated, we drove and walked in the vicinity of the experimental site. We found 17 vernal pools within 1,000 m of the site, many previously unknown, and numbered them sequentially with the prefix "TR" for "Travis." We have retained these original numbers for our own convenience in referring back to field notes. Pools TR6-TR13 lay west and downslope from our site, and had higher pH values (8.18-9.58) than pools TR1-TR5 and TR17, closer to our site (6.6-8.5). TR14-TR16 were immediately adjacent to where we intended to create pools, and were not big enough to serve as sources. In addition, pool TR16 had a good population of *Lasthenia conjugens* that C.D.F.G. wished us not to disturb.

TR1-TR5 and TR17 lay within the same or similar soil series as our creation site, and were approximately equidistant from it. We decided to use them as sources of inoculum and as reference pools for data with which to compare our created pools. (TR1-4 are in the Altamont clay of the zone of created pools; TR5 and TR17 lie in Antioch loam, which has similarly deep clay horizons.) Fig. 1.8 shows the relationships of these pools to our created pools and Fig. 1.10 portrays them in an aerial photograph.

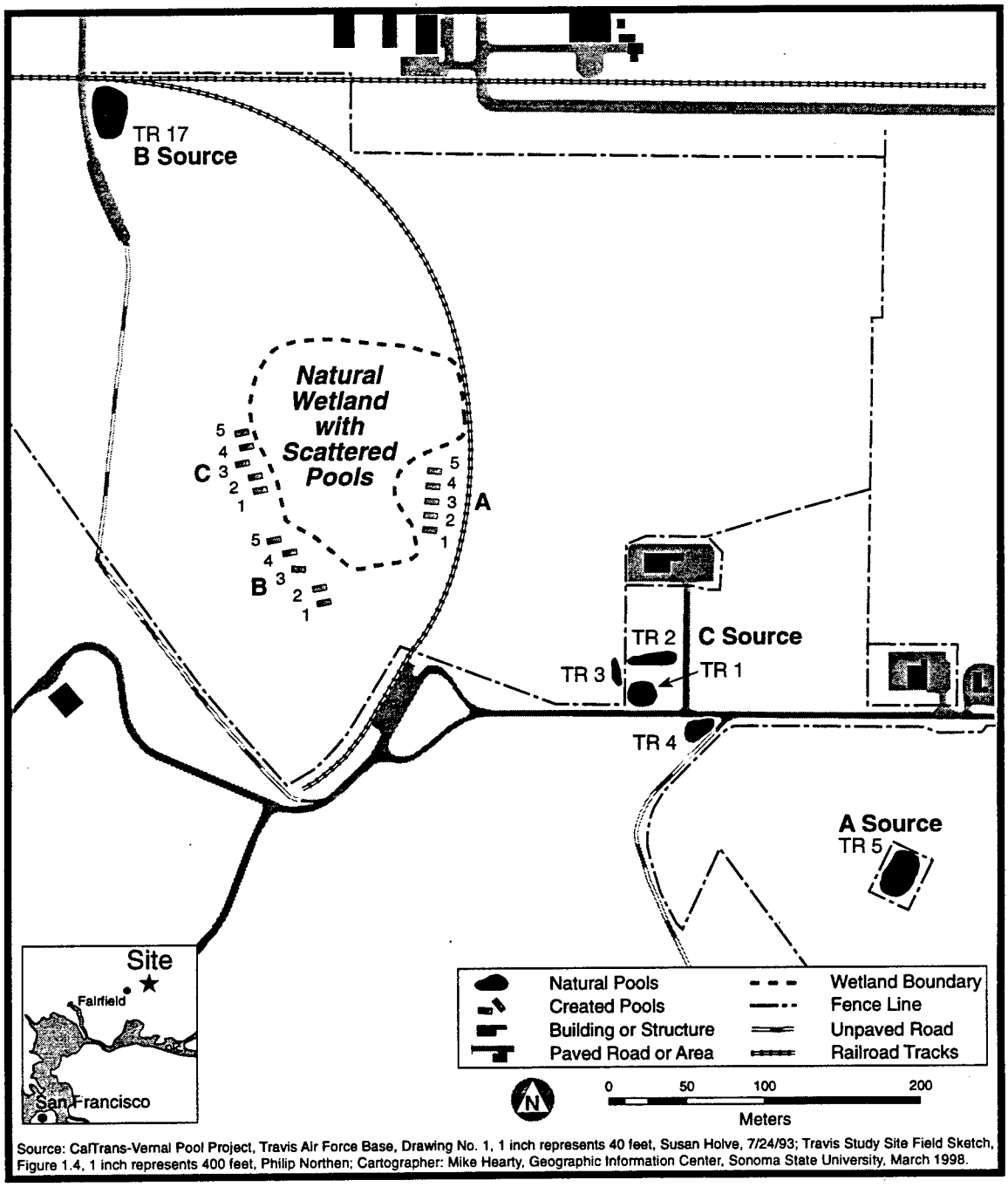


Figure. 1.8. Map of the study area, which lies near the western boundary of Travis Air Force Base southwest of the medical complex.

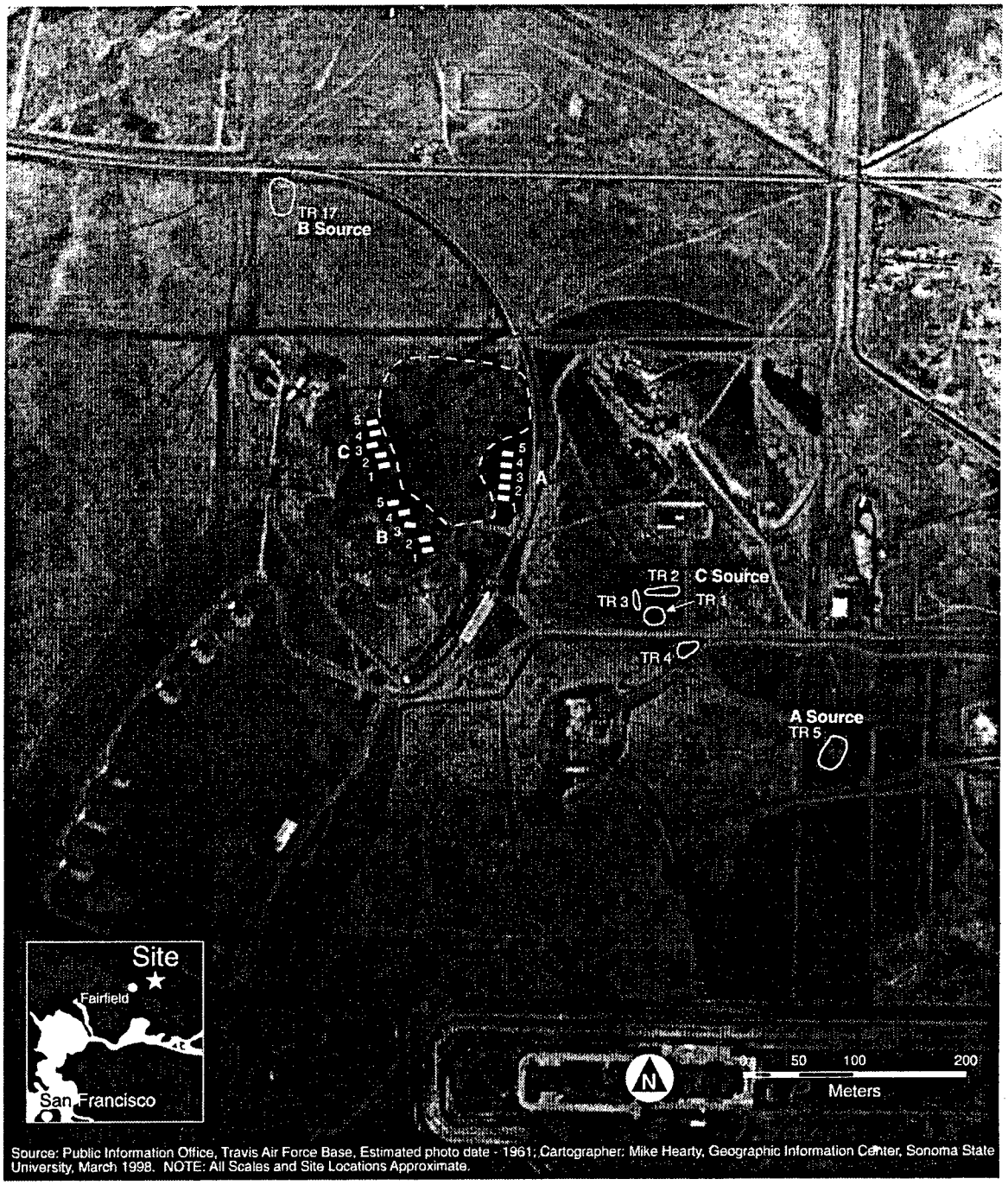


Figure. 1.9. Aerial photograph of the study area.

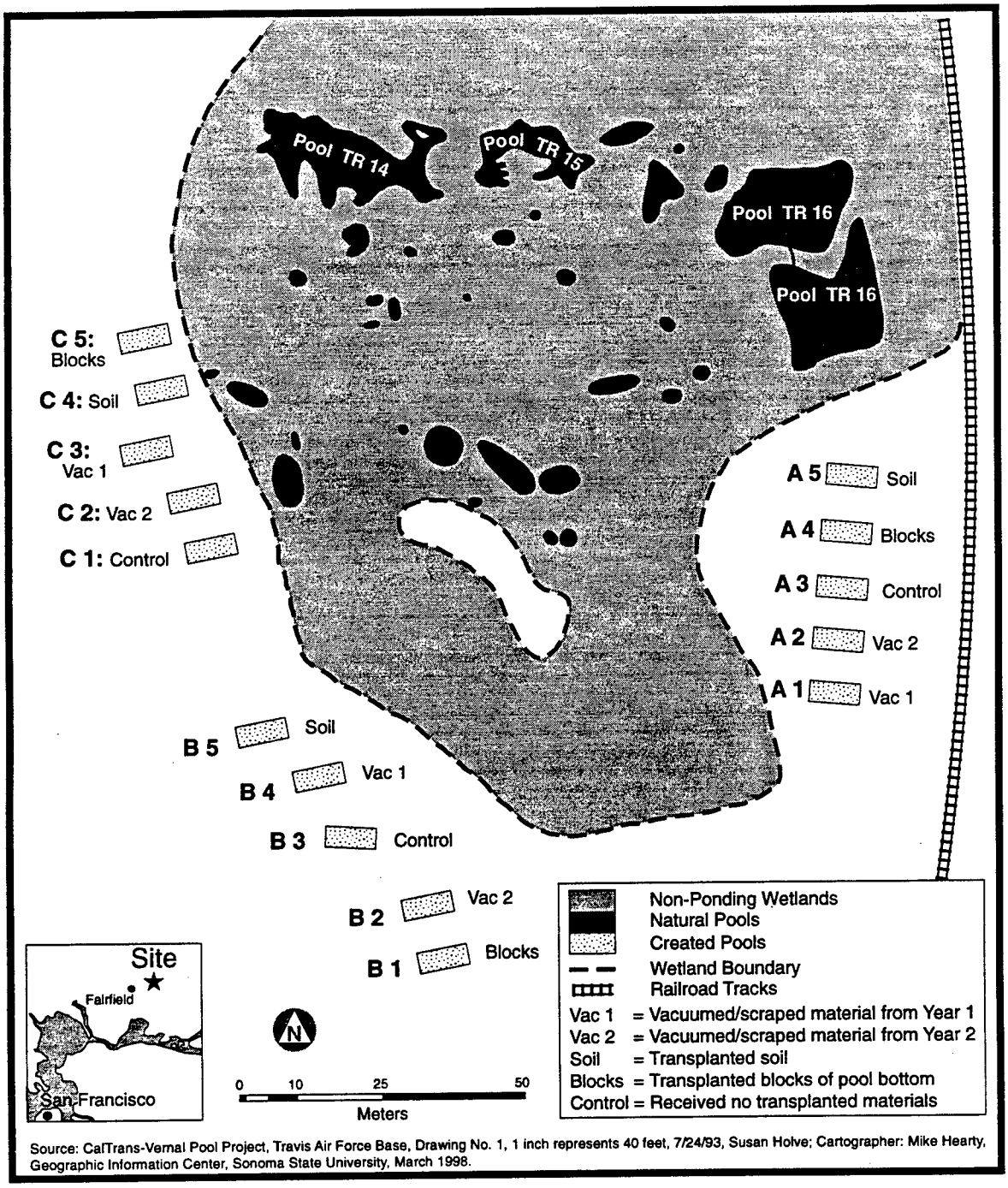


Figure. 1.10. Closeup map of the zone where created pools were located showing designations of the pools and inoculation treatments.

The pools can be described as:

TR1-TR4: Collectively served as the source for System C. A set of four small pools ranging in maximum depth from 17 to 30 cm and in area from 130 m^2 to 400 m^2. These lie about 250 m southeast of the created pools. TR1-TR3 nearly touch each other along a chain, and TR4 may have adjoined TR1 prior to construction of a road between them. TR1-TR3 have been disrupted by periodic disking, and have deeply pockmarked bottoms. TR4 has a smooth, hard bottom and may have been lightly graded in conjunction with maintenance of nearby roads.

TR5: The source pool for system A, depicted photographically in Fig. 1.11. A large pool that lies in a topographic bowl about 460 m southeast of the created pools. Most mesic of the source pools. It has a maximum depth of 45 cm and surface area of 1400 m^2. It has a population of *Eleocharis macrostachya* in places, a perennial native indicative of moister pools. Prior to the study, it was grazed heavily by horses. A few large rocks and chunks of asphalt indicate that people had occasionally used the pool to dispose of such items.

TR17: The source pool for system B, depicted photographically in Fig. 1.12. A large, flat-bottomed pool lying 250 m east northeast of the created pools. Maximum depth of 18 cm with a surface area of 1750 m^2. Heavily grazed by horses and cattle prior to the study, and periodically graded lightly to be used with the surrounding areas for various summer festivals on the air base. Generally used in the recent past as the site for a circus tent each summer. Had a small population of the federally-listed *Lasthenia conjugens*.

Lying between our sets of created pools, and at moderately lower slopes, were a number of irregularly-shaped, clay-bottomed pools, depicted in Fig. 1.10 with the results of our wetland delineation and the locations of the created pools in adjacent uplands. The largest of these had water depth to 30 cm. The pools contained *Pleuropogon californicus*, *Eryngium aristulatum* var. *aristulatum*, and *Callitriche sp.* in mid-winter, confirming the potential of the general area to support wetlands. Holmes felt that these wetlands may have been created by stripping of topsoil for use elsewhere on the base. A flora of the uplands and wetland species that occurred in our delineation appears in Appendix A.

Through February and March we monitored auger-dug test holes to examine the hydrology of the area. In and near the existing ponded areas of the creation site, water was within 10 cm from the surface throughout the winter, and this whole zone mapped as wetland in our delineation. In our upslope areas, the water table was also close to the surface, but typically 20-40 cm down. Our plan in pool construction was to intercept this water table with all of our pools.

Figure. 1.11. Photograph of source pool TR5 in Spring, 1994.

Figure. 1.12. Photograph of source pool TR17 in Spring, 1994.

In October of 1993, we marked the edges of our created pools on the ground with marking paint as 3 x 10 meter rectangles spaced 10 meters apart in three sets of five each, as depicted in Fig. 1.10. Using an excavator, Caltrans crews dug the pools. The deep end was first dug to a depth of 80 cm on the downhill portion of the marked rectangle. Then, keeping the dimension of three m wide, a flat plane was maintained for a distance of 10 m to the upper end of the pool at 0 cm relative to the deep end. Side slopes and slopes on the deep end were shaved to approximately 30 degrees, and the shallow end was tapered into the surrounding terrain.

The concept of having the pools equivalent hydrologically with respect to our samples is shown in Fig. 1.13, and actual data on their hydrological performance in this regard appears in methods for Chapter 2. Photographs in Fig. 1.14 depict a representative created pool for each inoculation method in the Spring of 1995, and Fig. 1.15 shows representative source plot collection areas one or two (SV1 method only) years following removal of inoculum.

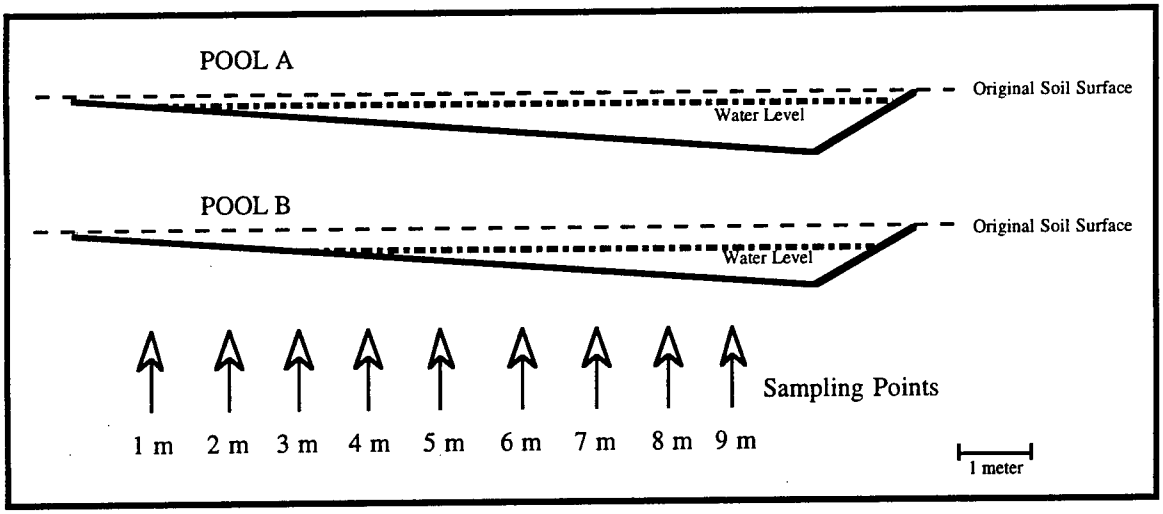


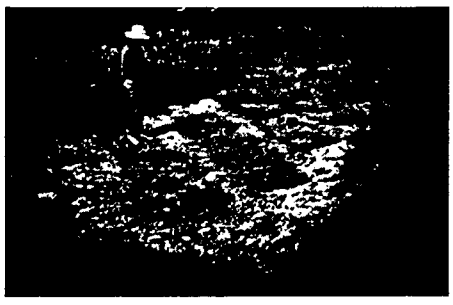
Figure 1.13. Scale diagram of the cross sections of two hypothetical pools that filled to different levels. Samples for Pool A would be taken at 2, 3, 4, 5, and 6 m, while those for Pool B would come from 4, 5, 6, 7, and 8 m, resulting in the two samples being taken at equivalent water depth.

Pool A3-Control

Pool A1-Vac1

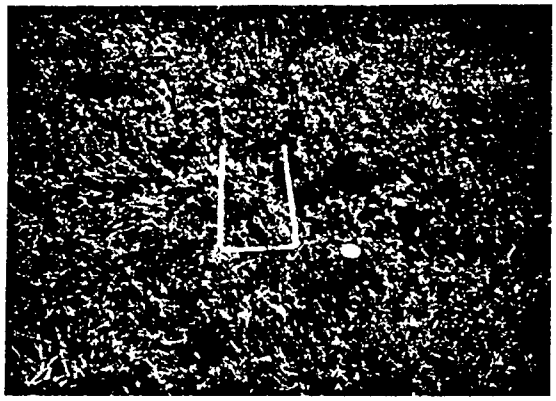
Pool A2-Vac2

Pool A5-Soil

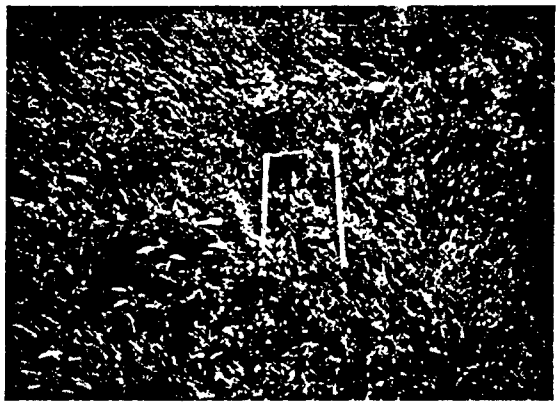


Pool A4-Blocks

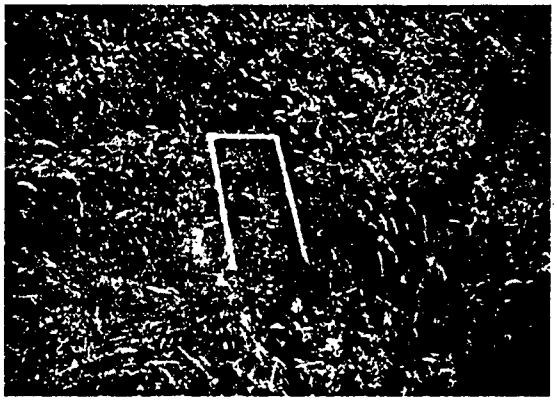
Figure. 1.14. Photographs of created pools of system A in late May, 1995.



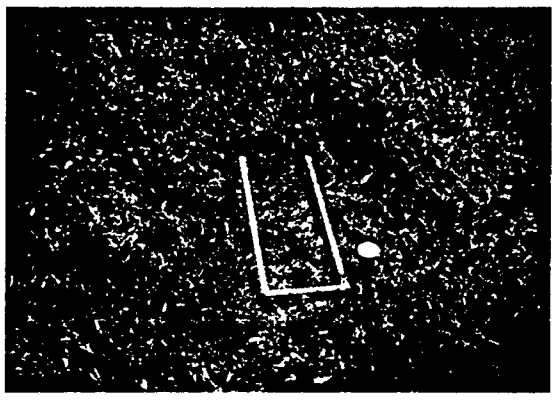
Scrape/Vacuum 1



Scrape/Vacuum 2



Excavation



Fill (after blocks removed)

Figure. 1.15. Photographs of representative 25 x 100 cm collection plots in Spring, 1995.

SUMMARY and IMPLEMENTATION

Each of the following chapters contains details of our results and conclusions on various aspects of the study, and we present a general summary here. Figures and tables to which we make reference are numbered with the first digit of their respective chapters, for example Fig. 3.14 is in Chapter 3. We have listed major conclusions by capital letter, enumerated the supporting data for each that is presented in the following chapters, and followed each conclusion with a brief discussion that includes ideas on how the finding may be implemented in vernal pool mitigation.

Conclusion A. Created wetlands in our study functioned as vernal pools during the 2-3 year time period of their existence.

All of our inoculated pools created functional wetlands. There were differences among them based on inoculation method, and information about this can be used to advantage in future restoration work, as outlined below. Our quantitative analysis showed that all of the inoculated artificial pools were successful to a high degree for plants and a moderate degree for aquatic invertebrates. The issue of "success," as pointed out by numerous people, requires long term data that go beyond the term of our work, and it would be valuable to continue monitoring our pools to see what the future holds. Success of the inoculated pools was seen by several measures:

1. Individual plant species showed patterns of success. Of 24 native wetland plants that had more than token presence in source pools, 21 survived into year 2 in inoculated pools. Sixteen of these showed good to high success as judged by comparing their relative cover in source and created pools. Furthermore, there was a strong relationship between the presence of species in inoculated pools and in the pools from which the inoculum was taken. Among all species with cover over one percent in sources, 33 of 37 were moderately to highly faithful in inoculated pools to their sources. Finally, 28 of these 37 species showed year-to-year changes in abundance that mimicked the pattern in source pools.

2. The inoculated pools effectively excluded upland species.

3. The inoculated pools in the second year had significantly higher relative cover and species/sample of native wetland plants than source samples. They did not differ

significantly in density of wetland natives. Average height of wetland natives was greatest in the source pools of 1996, and showed a significant treatment effect. The higher values in sources may be related to the adverse changes in composition of their plant communities discussed under conclusion D below. There was a significant effect of system in two of these tests, due to systematically higher or lower values in one or more of the pool systems than in the others. In all tests, however, the treatment effect had a lower p-value than that for system. This is notable because the source pools were quite different in their physical and botanical properties, yet the effect of our inoculation treatments was stronger than this between-system effect. Effects of year resulted from systematic change in all pools, including sources. Table 1.1 gives p-values for these effects, which can be seen graphically in Figs. 2.20-2.23.

Table 1.1. P-values from analysis of variance on the set of 1995 and 1996 samples for Vac2, Blocks, Soil, and Sources.

	p-value		
Response Variable	Treatment	System	Year
Rel. Cov. Wetland Natives	0.0003	0.2228	0.0753
# Wetl. Natives/Sample	0.0001	0.0034	0.0088
Density Wetl. Natives	0.0601	0.3253	0.0185
Height Wetl. Natives	0.0001	0.0071	0.7451

4. The inoculated pools in the second year had significantly higher relative cover, species/sample, density and average height of native wetland plants than uninoculated control samples. There was a significant effect of system in two of these tests. There were no effects of year in these comparisons, because values were generally rising slightly in controls and falling or remaining stable in inoculated pools. Table 1.2 gives p-values for these effects, which can be seen graphically in Figs. 2.20, 2.21, and 2.22.

Table 1.2. P-values from analysis of variance on the set of 1995 and 1996 samples for Vac2, Blocks, Soil, and Controls.

	p-value		
Response Variable	Treatment	System	Year
Rel. Cov. Wetland Natives	0.0001	0.0686	0.8096
# Wetl. Natives/Sample	0.0001	0.0444	0.2288
Density Wetl. Natives	0.0007	0.7614	0.1292
Height Wetl. Natives	0.0001	0.0202	0.8553

5. The inoculated pools developed functioning communities of invertebrate animals, but these were not quite as diverse as those of the source pools. The mean number of invertebrate taxa in our best inoculated pool type was 18.3 in 1996 compared with 24.3 in sources. A number of taxa were successful not only in the inoculated pools but in the controls; these species have widely spread propagules in soil of the area or they fly in to lay eggs. The invertebrates of the open water column were highly successful in inoculated pools, but success in forms that live on pool bottoms was mixed. Some were successful, but others weren't. We anticipate that development of a fully functioning benthic environment is a matter of time, but only additional data will confirm or refute this expectation. Statistically, there was a significant effect of treatment ($p \leq .0001$) when inoculated pools and sources were evaluated and Fig. 4.4 shows that higher values in source pools contributed in a major way to the effect. There was no effect of system and a significant effect of year ($p=.0325$). The year effect was due to increase in the number of taxa in all types of pools except Blocks, for which the 1995 and 1996 values were the same, and this increase lends credence to the idea that the invertebrate community will improve with time. There was a significant treatment effect in the set of inoculated pools and controls ($p=.0027$), but control pool averages lay just below those of two of the inoculated pool types in 1996. Year showed the same systematic increase as described above ($p=.0314$).

Discussion.

There continues to be argument about whether or not created vernal pools "work" or are "successful." Such arguments can be resolved only with controlled experimentation, and we have provided our contribution to that effort here. Our conclusion would obviously be stronger if the period of success could be evaluated over a longer period of time. Our work also applies primarily to the Northern Claypan type we studied (Holland 1986). Given the limitations, however, the performance of our inoculated pools does show that creation can be an element of mitigation.

We are aware that arguments against creation are often based on cost/benefit analyses regarding the cost of such projects in comparison with the number of natural pools that could be saved with the same funds. We are also aware that evolutionary and biogeographic considerations should play major roles in mitigation; created pools should not disrupt genomic isolation among species by

introducing new varieties where they don't belong. It goes well beyond the purposes of our work to analyze where creation should and should not be used.

Having said this, however, it seems reasonable to consider creation, or restoration of thoroughly degraded systems which is essentially the same thing, as desirable in some times and places, since it is the only way to adhere to the concept of "no net loss" of wetlands and potentially reverse the historical loss of wetland acreage.

Implementation.

1. Caltrans staff can use the results of our study to justify use of created wetlands to resource agencies. These will have success similar to ours if the soil is inherently capable of supporting wetlands, if the hydrology of the created wetlands is comparable to that of natural pools, and if proper techniques of inoculation are used.

2. Although not a result of our study, we recommend that creation of artificial pools be done in the context of conserving regional biogeography. We recommend that highest priority be given to restoring degraded wetlands and that second priority be given to using areas with suitable soils where the amount of existing wetland is small or non-existent. Created wetlands should rarely be added into areas already rich in vernal pools since such areas can provide scientific information on the natural processes of vernal pool ecology and on the relationships of uplands to the vernal pools. In situations where creation is appropriate, we recommend:

3. That inoculum be obtained from natural pools in or near the created pools, not from the impacted pools themselves, unless these pools are adjacent to the creation area or no closer sources are available. Transportation foreign inoculum into existing wetland systems significantly reduces their scientific value in the study of evolutionary and ecological processes.

Conclusion B. Waiting through one wet season before inoculating a pool does not improve success.

1. The plant communities of Vac pools were equivalent regardless of the year of inoculation. In the set of year 1 and year 2 data for Vac1 and Vac2, the relative cover, number of species per sample, density, and height of native wetland plants did not show significant treatment effects (Table 1.3). Data are shown in Figs. 2.16-2.19. Among these tests, system had a significant effect for number of species per sample, caused by lower values in system A and higher ones in system C. Height showed a significant effect of year due to a strong increase in Vac1 from year 1 to year 2 that essentially brought it to the same level as Vac2.

Table 1.3. P-values from analysis of variance on the set of 1994-95 Vac1 and 1995-96 Vac2 samples.

Response Variable	p-value		
	Treatment	System	Year
Rel. Cov. Wetland Natives	0.2547	0.1072	0.0576
# Wetl. Natives/Sample	0.5723	0.0136	0.0713
Density Wetl. Natives	0.7815	0.3842	0.1726
Height Wetl. Natives	0.5299	0.1658	0.0336

2. The number of invertebrate taxa in pools inoculated in year 1 and year 2 were equivalent two years after inoculation, ranging from 13 to 16 in all systems. In addition, pools of the same system but different years of inoculation had high numbers of shared taxa that rose from year 1 to year 2 (Table 4.9).

Discussion.

The essentially equivalent performance of pools with the different years of inoculation is surprising, because the first wet season, experienced by the year 1 pools (1993 inoculation) was below average and the next year was a normal one (see Appendix A for rainfall averages and Table 4.2 for information on hydration of the pools). We were remiss in not obtaining turbidity data for year 1, but experienced a technical problem that prevented us from documenting changes. Despite this, however, both the plant and invertebrate communities responded equally in the two pool types.

Implementation.

The use of this conclusion is that those undertaking restoration need not feel compelled to delay inoculation for biological reasons. A year's delay in inoculation may often be advisable for other reasons, such as confirming the hydrological conditions of a created pool before inoculating it.

Conclusion C. Inoculating created pools with pulverized soil is superior to vacuum/scrape and block methods in creating successful vernal pools.

1. Soil outperformed the other two inoculation methods in four measures of success for native wetland plants: relative cover, species/sample, density, and height. The treatment effect was statistically significant for relative cover and height, as shown in Table 1.4. Figs. 2.20-2.23 show the data graphically and give the averages. The strong system effect for species/sample was due to there being greater species richness in inoculated pools of system C and lower diversity in system A. For height, which also showed a system effect, C had lowest values. Combined, these suggest that small annual plants had a greater presence in system C. The effect of year for species/sample was due to a decline in species/sample in all inoculated pools over two years, a phenomenon that will be discussed more in Conclusion D.

Table 1.4. P-values from analysis of variance on the set of 1995 and 1996 samples for Vac2, Blocks, and Soil.

	p-value		
Response Variable	Treatment	System	Year
Rel. Cov. Wetland Natives	0.0108	0.1264	0.3391
# Wetl. Natives/Sample	0.2853	0.0075	0.0128
Density Wetl. Natives	0.1640	0.6905	0.0834
Height Wetl. Natives	0.0001	0.0066	0.6948

2. Soil had the greatest diversity of invertebrate taxa in year two among the three inoculation methods. In comparison with 24.7 taxa on average in source pools in 1996, it had an average of 18.3 per pool compared with 14.7 for Vac2 and 13.7 for Blocks (Fig. 4.4). When both years were included in

analysis of variance for the inoculated pools without sources or controls, the effect of treatment was not significant but was low (p=.0508). There was no significant effect of system or year.

3. Measures of percent similarity indicated that Soil produced the best match between source pools and created ones for the invertebrate communities. Here we used similarity to uninoculated controls to represent lack of success and similarity to sources to represent success. Soil was notably least similar to controls, and ranked equal to Vac2 in similarity to sources in 1996 (Fig. 4.8; statistical results in Table 1.5). In these matches of the invertebrate communities to sources, there very strong effects of system: system A ranked universally most similar to controls and least similar to the source. The percent similarity to plant source samples was not significant, but Soil (40%) and Blocks (41%), did have higher values than Vac2 (29%) (Fig. 2.24). In this test there were significant effects of system (C had the lowest match and A the highest), and year (all values decreased in 1996) (Table 1.5).

Table 1.5. P-values from analysis of variance on the set of 1995 and 1996 similarity indices for Vac2, Blocks, and Soil.

	p-value		
Percent Similarity	Treatment	System	Year
Plants: Inoc. Pool to Source	0.6713	0.0309	0.0065
Inverts: Inoc. Pool to Control	0.0131	0.0057	0.7571
Inverts: Inoc. Pool to Source	0.0214	0.0099	0.3078

Discussion.

Our finding that transfer of soil is the most effective method of inoculation is of considerable economic importance to those engaged in restoration or creation of vernal pools, because removing soil as an inoculum can be done easily with heavy equipment and is therefore by far the most cost effective method. There is also no reason to add vacuuming to the method, since one would not improve performance by doing so. We will see in Conclusion E below that soil removal may be preferable to scraping/vacuuming as far as impact on pools goes. Considering both effectiveness and impact on source pools, the simplest technique for inoculation is not only adequate, but it is actually preferable to others.

Our method of placing soil blocks on the bottoms of pools differed from that of Wymer in her transplant, hence our result may not entirely represent the best that the method can do. To assure comparability among our treatments, we had to assign the blocks to random positions in the pool as we did the soil and scraped duff and seed. Some of the plants in our blocks of sod therefore found themselves under different hydrological conditions than they had just come from. In Wymer's transplant, each block was put in its original place in the pool. We have shown, however, that a much less costly method of inoculation, using soil as inoculum, produces excellent results. In addition, Soil outperformed Blocks substantially in terms of the success of the vernal pool invertebrates.

Transplant in some projects has relied primarily on mowing and collecting seed by hand, such as in the recent study near Fresno by Stebbins, Brownell, and Trayler (1996). Such methods will still be valuable, and presumably have less impact on source pools than two of our methods. They can also help in amplifying particular target species. They do limit the collection to seed to the particular species that were successful in the year of collection, however, and transfer primarily plant propagules. If such collection is done vigorously enough to create bare areas akin to our scraped and vacuumed ones, the impact on pools may actually be greater than that of soil removal (see Conclusion E).

Implementation.

Caltrans restoration biologists can use the simplest method of pool inoculation, soil and the plant matter that comes with it, as inoculum in created pools. In our study, we applied soil approximately 10 cm deep in created pools and removed it on plots in source pools to a depth of 15 cm by hand. Such removal could be done mechanically, however, with equal effectiveness.

Since we found that scraping and vacuuming the surfaces of natural pools resulted in some invasion by non-native wetland plants (conclusion E below) soil from natural pools should be removed in a manner that obviously deepens the removal area. Such deepening will make it harder for non-natives to invade since most of them prefer the shallow zones of pools. It may be possible to simultaneously obtain inoculum and increase the diversity of a source pool by diversifying the habitat the source pool with one or more slightly deeper areas.

Conclusion D. The source pools in our study lost plant diversity rapidly over four years and began developing thatch. Evaluation of success in created pools must take account of changes taking place concurrently in source or reference pools. "Self-sustainability" as a criterion of success for created pools is only valid within the context of appropriate disturbance regimes.

1. Fencing of source and created pools was necessary to control conditions of the study, but led to notable changes in the source pools. The percentage of plots containing bare ground decreased markedly (Fig. 2.8) while those containing thatch jumped (Fig. 2.13). The percentage of plots containing non-native wetland plants like *Polypogon monspeliensis* and *Rumex crispus* also increased markedly while those with native annuals fell (Figs. 2.10 and 2.11). The density of wetland natives more than tripled in the second year following fencing, but by the fourth year had dropped to half the original value (Figs. 2.18 and 2.22).

2. The inoculated pools outperformed the source pools in their first two years in a number of measures (conclusion A above). Despite this, inoculated pools also experienced declines in species richness (Fig. 2.21) and a number of plants disappeared or declined in the inoculated pools from year 1 to year 2 (Fig. B1, Appendix B). If success were being measured by comparison of inoculated pools only to values in source pools from the year of inoculation, one might have concluded that the created pools were beginning to fail. In fact, they were undergoing changes that were normal for the region.

3. Use of indices of similarity between inoculated and source pools served as one criterion by which created pools were evaluated in comparison with the rapid changes in the source pools, and should be considered for evaluating success of created pools in other projects. In such evaluations, source samples in successive years must be evaluated for their similarity to the original source samples to provide a baseline of comparison, such as we did for plants (Fig 2.24).

Discussion.

Our source pools were highly disturbed before the study, nonetheless they had maintained high diversity. One would probably not produce a conservation and

management plan for a vernal pool in which it would be used each year as the site for a circus tent (the past management of pool TR17, system B), nor would one disc the pool each year (pools TR1 and TR2, system C). Initially it may seem that such disturbed pools do not provide an adequate baseline for study, and that their strong response to protection is atypical. We have observed such changes in shallow swale ecosystems in Sonoma County however (the Todd Road Preserve), and the Nature Conservancy is actively pursuing burning and grazing as management tools for two of the most significant vernal pool systems in the state, the Vina Plains Preserve in Tehama County, and the Jepson Prairie just east of Travis Air Force Base. After discovering a population of the now federally-listed *Lasthenia conjugans* just west of pool TR17 on the site visit to review our project, a C.D.F.G. representative recommended that grazing be stopped where it grew. Absent grazing, it has disappeared. By contrast, Pool TR16 (Fig. 1.6) adjacent to our created pools is disked annually and has maintained its population of *L. conjugens.*

We believe that our source pools are typical of the majority of vernal pools in the Central Valley in needing regular disturbance for maintenance of their diversity and other values. In this light, the concept of self-sustainability as a success criterion for a created pool needs to be redefined.

Implementation.

Caltrans should assure that success of created vernal pools is gauged only in comparison with nearby natural reference pools, otherwise loss of diversity and other values in created pools could be interpreted as failure. The index of similarity is a simple quantitative means for determining how changes in created pools relate to similar changes in source pools.

Much attention needs to be given to establishing management regimes that allow natural pools to maintain themselves, and the success criterion of self-sustainability for created pools must be modified to require that they continue to function with appropriate disturbance regimes as part of their management.

Conclusion E. **Our removal plots differed in how they affected natural pools. Although all forms of plot treatment increased native plant diversity, scraping/vacuuming and adding fill led to higher cover and species richness of undesirable non-natives. Creating shallow, unfilled depressions by removing soil had no adverse effects, and is the preferred method for removing inoculum.**

1. By examining graphs of trends in relative cover for individual species and using analysis of variance to see which trends were significant, we were able to identify 13 small native wetland plants, all of them annuals but the tiny fern *Pilularia americana*, that have or will shortly disappear from source pools. We established a set of "small natives" containing these 13 plants plus one additional small annual. We then evaluated the affect of our methods on relative cover of this group and the number of species from the group present in the average sample. Over two years, there was a significant effect of treatment (including SV2, Exc, Fill and Ref) on these small natives. They were doing much better on all of the removal plots than on the reference plots, and best on Fill (Figs. 3.14 and 3.15; Table 1.6). The effect of system seen in the table is due to one system having lower values and another high, and the strong effect of year is because all plots were showing rapid decline. The removal of inoculum was thus a short term benefit for these plants, but the plots will be expected to decline eventually as have the pools themselves.

Table 1.6. P-values from analysis of variance on small native plants on collection plots of three types in source pools and on reference plots (SV2, Exc, Fill, and Ref).

	p-value		
Response Variable	Treatment	System	Year
Rel. Cov. Small Natives	0.0011	0.0026	0.0001
# Small Natives/Sample	0.0006	0.0041	0.0001

2. We identified a group of six larger native wetland plants that are increasing in pools or maintaining their populations. They are likely to persist. All of the methods for treating collection plots harmed one or more of these plants (Fig. 3.16) but they showed evidence of recovery on the plots.

3. During the dry winter of 1994, three non-native wetland plants invaded the SV1 plots (*Briza minor*, *Lolium multiflorum*, and *Lythrum hyssopifolium*,

Fig. 3.10-3.12), and this invasion was much greater than on the equivalent SV2 plots in the following, wetter year. Not only did they invade, but the first two species increased in successive years, apparently suppressing natives like *Downingia concolor*. The conditions in the year following removal of inoculum can set initial conditions for some invaders to have adverse affects on native plants that stretch over at least several years.

4. In addition to the three non-natives listed in the previous section, four non-natives were increasing in the source pools but did not have notably strong presence in 1994. These are *Cotula coronopifolia*, *Polygonum arenastrum*, *Polypogon monspeliensis*, and *Rumex crispus*.

5. In order to see the overall affect of the removal plot methods on non-natives, we pooled the seven listed in (3) and (4) above into a group of "successful non-natives" for analysis of variance. Both relative cover of this group as well as the number of these species per sample showed a significant effect of treatment (Table 1.7, Figs. 3.18 and 3.19). Excavated plots left alone retarded the cover and richness of these non-natives, even in comparison with the reference plots, while the SV2 method, and even more so the Fill method, increased their values. Neither variable showed an effect of system, but year did have a substantial effect, seen in figures as the increase from one year to another on all types of plots.

Table 1.7. P-values from analysis of variance on successful non-natives on collection plots of three types in source pools and on reference plots (SV2, Exc, Fill, and Ref).

	p-value		
Response Variable	Treatment	System	Year
Rel. Cov. Small Natives	0.0001	0.2710	0.0001
# Small Natives/Sample	0.0043	0.0696	0.0008

Discussion.

The scraping and vacuuming technique enabled undesirable non-native plants to gain a foothold in the ecosystem in a dry year. Because of the design of the experiment, we do not have data on other types of plots in that year. During the wet year, all types of removal enhanced diversity and cover of natives in

comparison with reference plots, but the scrape/vacuum and fill methods had the significantly adverse effect of encouraging non-natives. By contrast, the excavation method also enhanced diversity and cover of natives, though not as much as filling the plots with soil, but it did not accelerate the invasion of non-natives in comparison with reference plots. Clearly this method is preferable to the other two.

One reason the excavated plots resisted invasion may be that they slightly deepened the water of the pool. *L. multiflorum*, *B. minor*, *L. hyssopifolium*, *Polygonum arenastrum*, *Polypogon monspeliensis*, *C. coronopifolia* and *R. crispus* are all facultative (FAC) or facultatively wet (FACW) plants (U.S. Army Corps of Engineers terminology as given by Reed (1988) for individual species, meaning that they withstand inundation somewhat less well than the obligate wetland (OBL) natives most common in vernal pools. The deeper water may have disfavored this particular set of non-natives. In pools with deeper standing water, therefore, the scrape/vacuum technique may not have a disadvantage, or for that matter neither may Fill.

Implementation.

An important application of our results is that it is acceptable to remove soil from pool bottoms, and not worry about special treatment to avoid harming pools. Our plots were a maximum of one m^2 in area, so we can't generalize to significantly larger areas, but removal in a configuration that allows recolonization of removal areas up to a m wide should be acceptable. It would be advisable to obtain quantitative data on the removal plots in a few more projects, however, to test the generality of our result. In addition, the depth to which soil should be taken was probably maximal in our study at 15 cm. For small plots this is a suitable size because each plot is exposed to nearby seed sources. For larger plots or slightly contoured depressions, such as might be done with a bulldozer, about half this depth seems intuitively to be better.

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Chapter 2- Plants in Source and Created Pools

INTRODUCTION TO MAJOR QUESTIONS

Study of the plant communities was based on obtaining data each year on natural pools, which were the the sources of inoculum for created pools, and on the resulting created pools themselves. We compared species richness and other measures of success in the source and created pools. As given in more detail in Chapter 1, the experiment was replicated three times in each of three "systems," A, B, and C, each of which contained a source pool, four created pools that were inoculated by different methods with materials from the source pool, and a fifth created pool that was not inoculated. In system C we used a set of four small pools adjacent to each other as our source.

The systems were: (A) source pool TR5 and created pools A1-A5; (B) source pool TR17 and created pools B1-B5; and (C) source pools TR1-TR4 and created pools C1-C5. Two inoculation methods involved scraping and vacuuming materials from plots in the source pools: "Vac1" designates this method performed before rains in the Fall of 1993 and "Vac2" the same method done in Fall of 1994. "Blocks," the third method, involved removing whole pieces of the pool bottom, while "Soil" used crushed soil as the inoculum. Both of these methods were also done in Fall, 1994. In order to avoid selective use by livestock of one created pool over others and to protect the stakes needed to mark plots and transects, all pools were fenced for the duration of the study. We undertook to determine:

1. if there were systematic changes in the plant communities of the source pools that might provide a context for interpreting results in the experimental pools and lead to other management recommendations;

2. what proportion of individual species could be judged to have been successful in created pools, and the degree of success of these species;

3. the degree to which the species composition and year-to-year levels of abundance in created pools reflected those of source pools;

4. if waiting one year before inoculating a pool would lead to greater success than introducing source materials in the year of construction;

5. if one of three methods of inoculation (Vac2, Blocks, and Soil) produced greater success:

6. the degree to which overall similarity in species composition between inoculated pools and source pools indicates success in the creation effort.

A number of tabular summaries of the data as well as graphical interpretations are given in Appendix B, where common names of all plants are also given.

LIST OF MAJOR CONCLUSIONS

1. Source pools underwent a loss of diversity over four years as the areal extent and cover of a number of smaller native plants declined, while these values for larger plants, including several non-natives, increased. The success criterion of "self-sustainablilty" often applied to creation projects, if taken to mean that the created habitat will perform in complete protection from regional disturbance, is untenable. Absent some disturbance that mimics unknown prehistoric conditions, diversity in most pools can be expected to decline.

2. Twenty-one of 24 native wetland plants from source pools survived into year 2 in the inoculated pools and few were present in the controls. Of the 24, 16 showed good to high success in one or more of the inoculation treatments. The inoculated pools excluded upland plants, many of which are non-natives, very well. The general conclusion is that pool creation does create a diverse flora equivalent to that of source pools within the time frame of the experiment.

3. The inoculated pools had plant species closely derived from their sources and with populations undergoing similar year-to-year trends. Among species in inoculated pools with relative cover values in source pools greater than 1%, a large proportion (33 of 37) were moderately to highly source-faithful, occurring in inoculated pools of the same system as the source pool. Twenty-eight of 37 were moderately to highly faithful in tracking the same year to year trends in inoculated and source pools.

4. By the second year, there were no significant differences in four measures of native wetland plants in pools inoculated in the year of construction and those inoculated a year later. These pools, inoculated with the Vac technique, had more native species per sample than source pools but the difference was not significant. They were equivalent in relative cover of

natives, but had significantly lower average density and plant height than source pools. Uninoculated control pools increased in all measures over three years, but were still significantly lower in these measures than inoculated pools.

5. Among inoculation treatments, Soil outperformed Vac2 and Blocks in four measures of success for native wetland plants: relative cover, species/sample, density, and height, with statistical significance for relative cover and height. Blocks and Vac2 each ranked second in two of the four factors. Inoculated pools had values significantly higher than source pools for relative cover and species/sample, and higher values for density in the second year. Height was greater in source pools, but this may or may not be considered "success," since it results from a decrease in native annuals. Inoculated pools were significantly better than controls in all of these measures, but values increased each year in the control pools, indicating that they are slowly being invaded by native plants.

6. Inoculated pools very closely resembled source pools in how species composition changed over two years. In each year following the 1994 inoculation of Vac2, Blocks, and Soil, the source pools became less similar to their own original composition. By 1995, percent similarity on average of sources to themselves was just above 50%, and by 1996 it had dropped to 40%. These changes in source pools have been summarized in Conclusion 1 above. The Blocks and Soil inoculated pools had values from 49- 51% similarity to sources in 1995 and 40-41% in Blocks and Soil in 1996. These two inoculation treatments expressed trends in "similarity to sources" equivalent to the changes in the sources themselves. Vac2 had a value of 29% in 1996, the least similar among the treatments.

METHODS

Plant sampling methods. In both the source and created pools, we took data along transects at selected points through pools, and randomized the exact position of data-gathering plots along these transects. For source pools, transects were located to cross pools at permanently marked points 25%, 50%, and 75% of the distance from the end of the pool (Fig. 1.2). In addition to providing a subset of data for comparison with both the created pools and plots from which source materials were taken, the baseline transects provided information on changes in the abundance and spatial extent of species in the source pools themselves.

All data were taken by Susan Holve-Hensill. To mark plot edges, she used a sampling device with dimensions of 20x50 cm constructed from 5/8 inch PVC pipe. One end was left

open, creating a three-sided structure that could easily be slid into the vegetation (Fig. 2.1). In the late spring and early summer of 1993-96, starting at the 1 m point of a tape laid the length of each source pool transect and then repeated at 1 m intervals, Susan placed the center of the short side of the device at each meter point and 30 cm before and after it, selecting a random number to place the plot either right or left of the transect line. For example subsamples would be taken at 6.7 m (left or right at random), 7 m (left or right), and 7.3 m (left or right) to represent the 7 m point on the transect (see Fig. 2.2). Before analysis of the data, the numbers from these three subsamples were pooled so that each meter point on each transect was represented by one number for each variable. Throughout the analysis, "sample" refers to the pooled data from these three subsamples. (In 1993, data were inadvertently taken every 2 m along transects of Pool TR5, the source for system A. This did not greatly affect comparability with future years.)

For the created pools, two transects were established parallel with the long axis of the pool and starting at a marked point at the shallow end. These transects were set 1 m in from each edge of the 3 m wide pool. For the final analysis of data, we selected the ten samples for each pool starting 1 m into the pool from the high water point. By doing so, all of the samples were taken in created pools at equivalent average water depths. Fig. 2.3 represents this sampling geometry.

Figure 2.1. Photograph of the plant sampling technique.

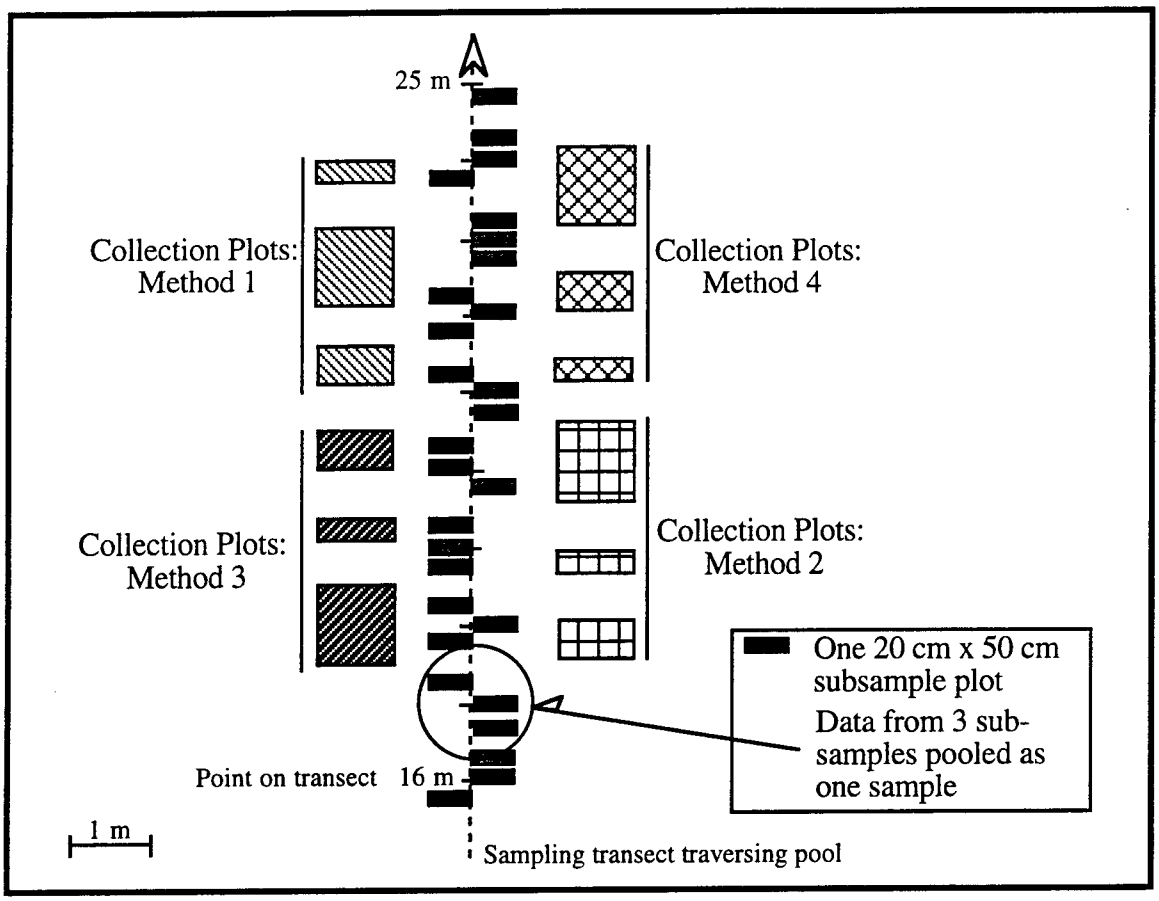

Figure 2.2. Diagram of sampling and collection plots on a segment of a baseline transect in a source pool. (See Fig. 1.2 for a diagram of how transects were located in pools and a discussion of transplant methods.)

For each plant species in each subsample (as well as for bare ground, thatch, and other non-living items) Susan made a visual estimate of the total amount of the plot covered by that species (percent cover). She also measured the average height of that species in the plot. We determined density by having her note what length of the rectangular subsample held 10 plants, and converting this area for ten plants (for example 23 cm of length x the 20 cm plot width) to plants/m^2. For situations where 1-9 plants occurred in the entire 20 by 50 cm plot, this number was divided by the total plot size and then converted to plants/m^2. Susan called out the numbers, and an assistant immediately entered them into a database ("Panorama" produced by the ProVue Development Corporation, Huntington Beach, CA) on a Macintosh PowerBook 170 laptop computer.

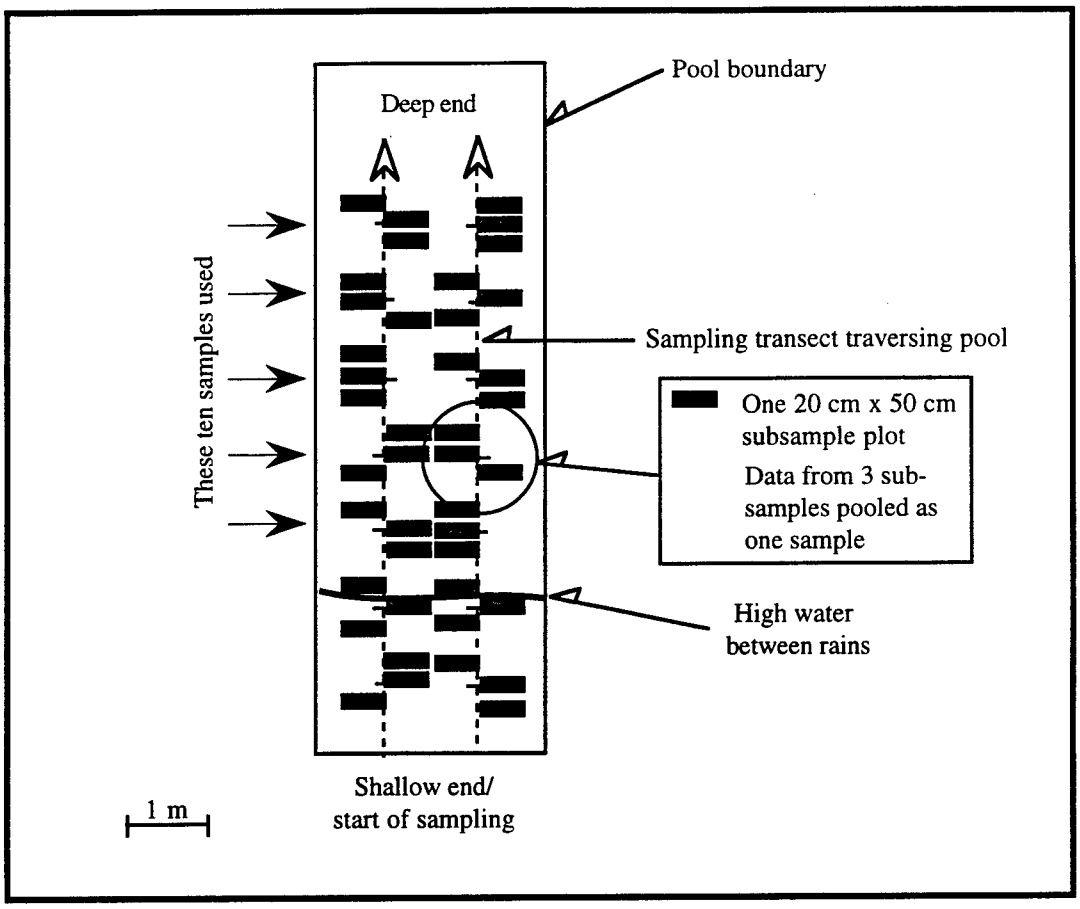

Figure 2.3. Diagram of the sampling plan for a typical created pool.

Hydrological data and its use in selecting zones for analysis in created pools. At approximately two week intervals throughout the rainy season, we measured the depth of water in the created pools at each meter point from the sampling baseline using a meter stick. These measurements were made from the shore of the pools to avoid disrupting them, and the stick was wiped clean between pools. We plotted these data for the entire sampling year of 1995-96 for each pool, which was a wet year with hydration of the pools over an extended time (see Table 3.2 in Chapter 4).

As anticipated, the pools did not all fill to the same level (Fig. 2.4). By basing our analysis only on the data for each pool from the 10 samples downhill from the high water mark (five samples on each of two transects), as depicted in Fig. 2.3, the sampling zones were made very closely equivalent. In hydrological graphs below, the five points down from high water are referred to as "adjusted distance." Graphs show that for each of the sets of five created

pools in a given system, designated A1-A5, B1-B5, and C1-C5, water depths at the adjusted distances were very close to each other (Figs. 2.5-2.8).

Only in Pool A1 (Fig. 2.8) were the depths at these adjusted distances more than minimally different from those of other pools in a system. This pool was the control for that system, which makes the difference of less concern than it might otherwise be because of the very large differences between treatments and controls in all systems (see Results below).

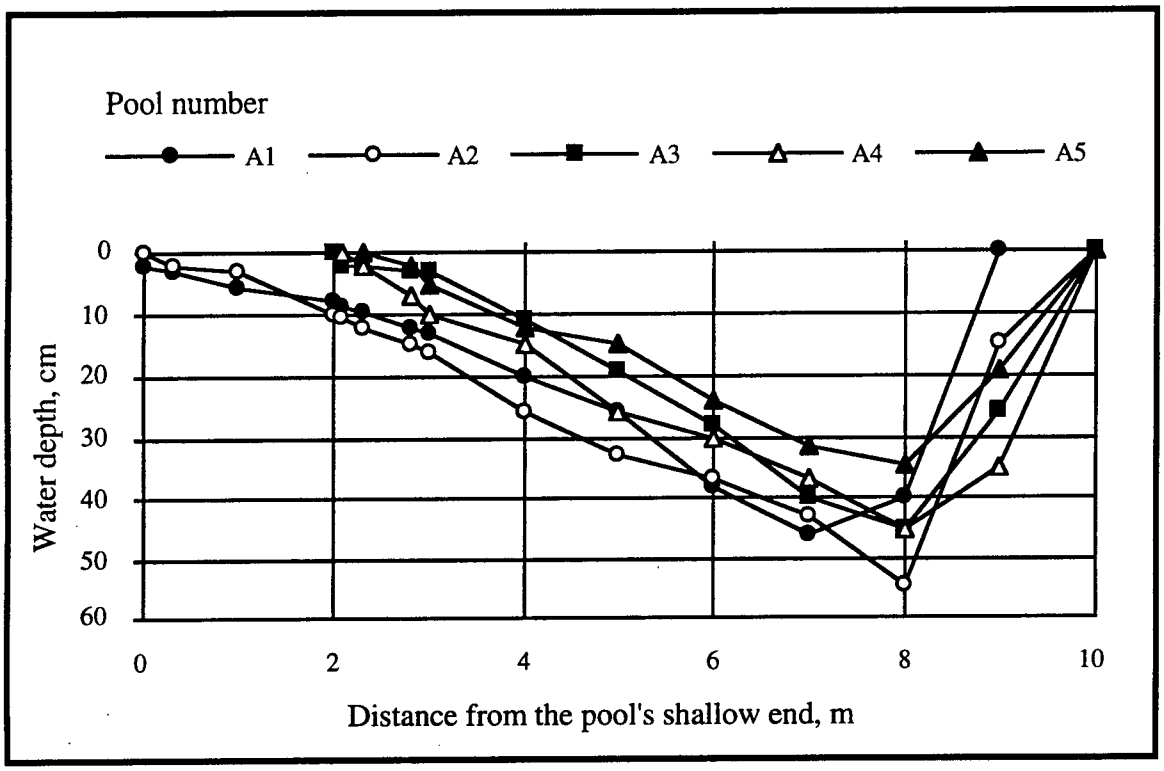

Figure 2.4. Water depths of a representative created pool system in the middle of the wet season, system A on 25 Feb 1996. Adjusted distances were selected so that the starting point of 1 m adjusted distance was 1 m for pool A2, 2 m for pools A1 and A4, and 3 m for pools A3 and A5. Fig. 2.5 shows water depths at these adjusted distances.

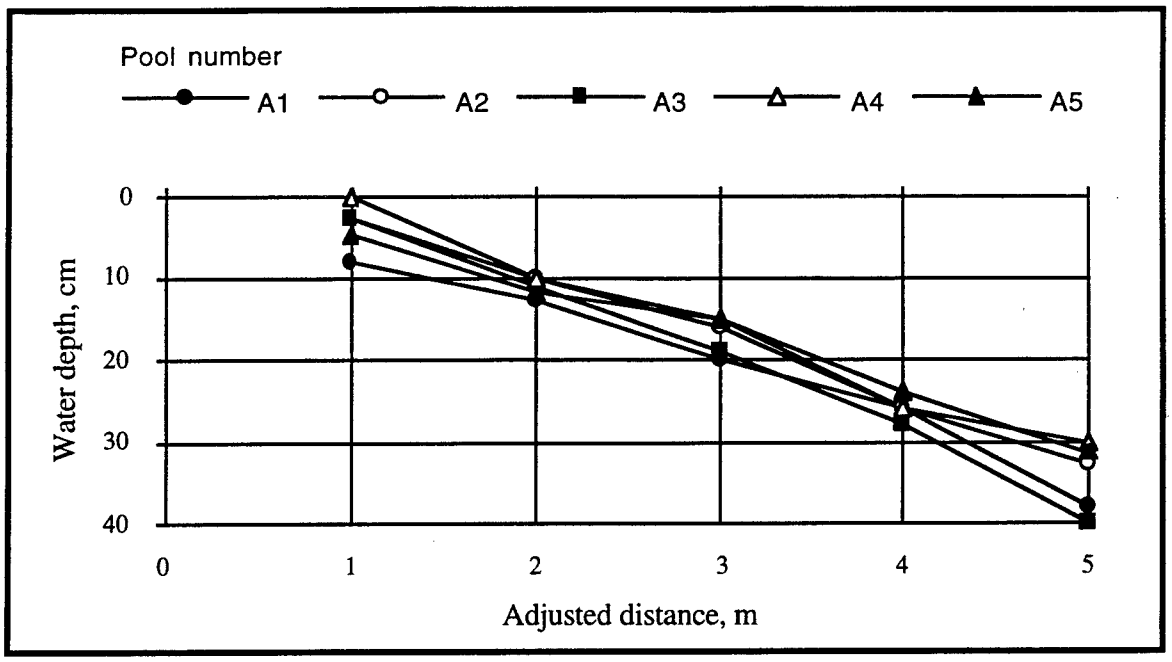

Figure 2.5. Water depths of the created pools in system A at mid-season (25 Feb 1996) at each of the adjusted distances (see Fig. 2.4). Samples from these adjusted distances represent the pools in the plant data analysis.

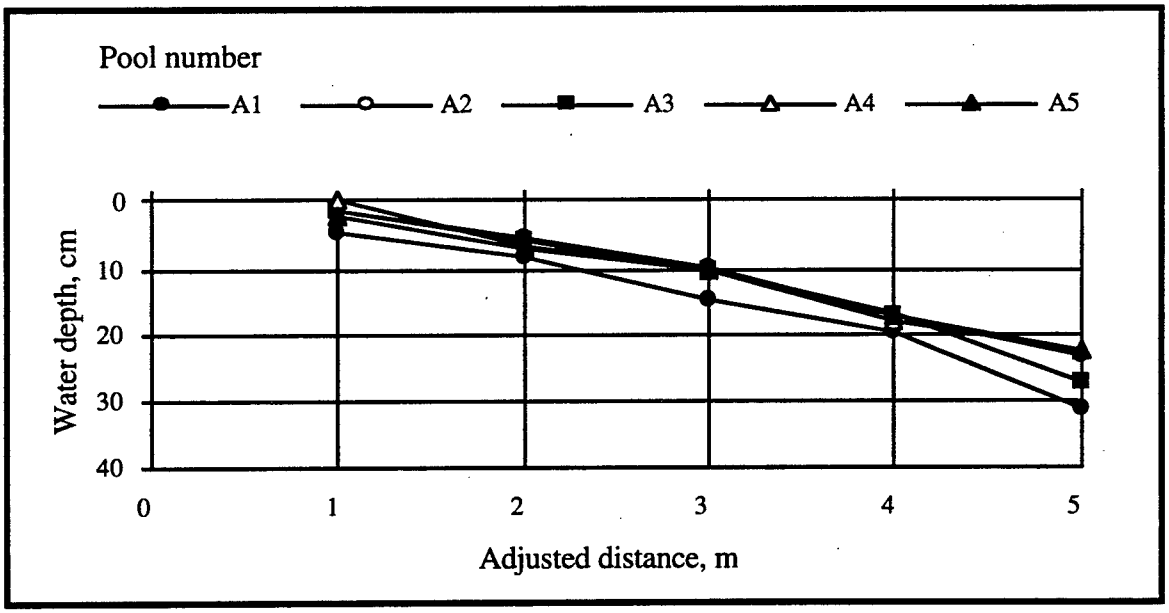

Figure 2.6. Average water depths of the created pools in system A over the 1995-96 wet season at each of the adjusted distances (see text). Samples from these adjusted distances represent the pools in the plant data analysis.

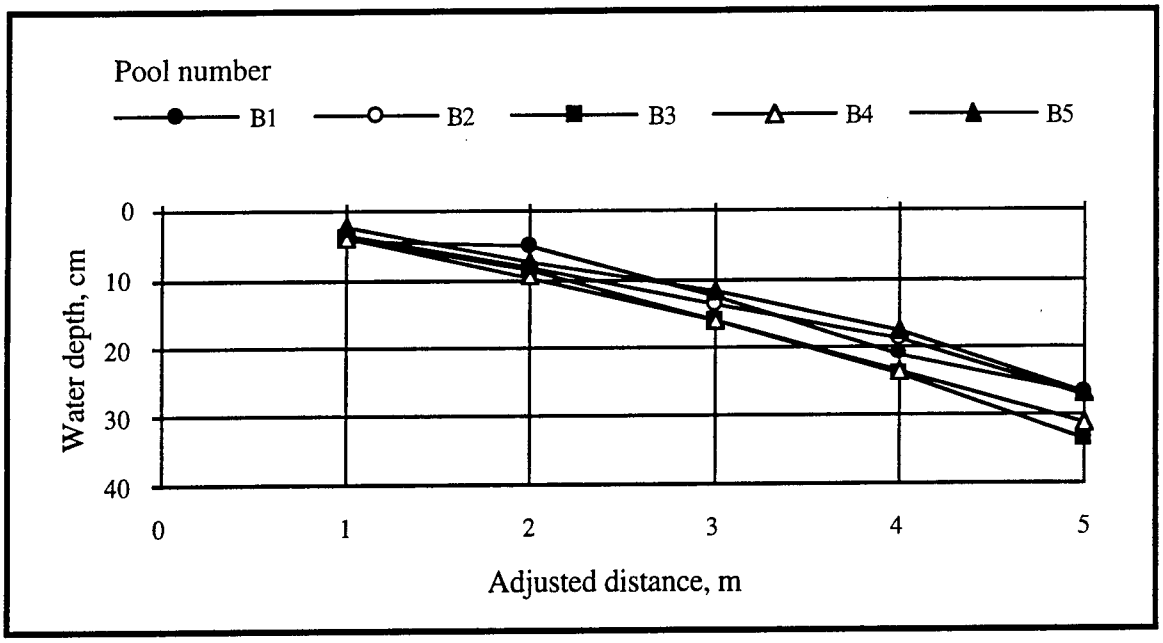

Figure 2.7. Average water depths of the created pools in system B over the 1995-96 wet season at each of the adjusted distances (see text). Samples from these adjusted distances represent the pools in the plant data analysis.

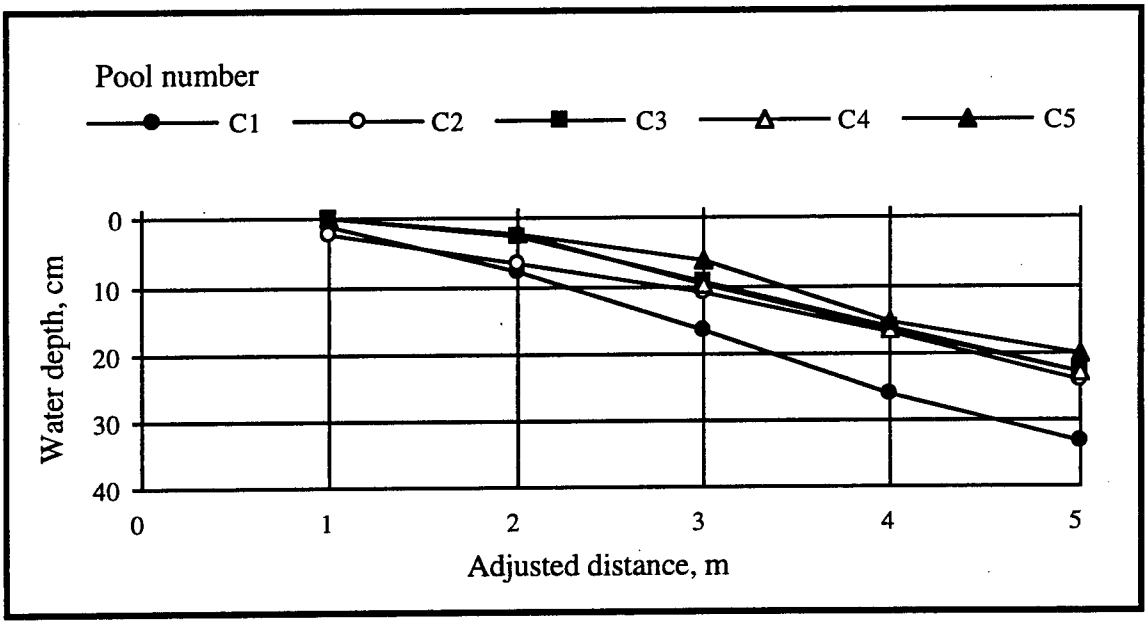

Figure 2.8. Average water depths of the created pools in System C over the 1995-96 wet season at each of the adjusted distances (see text). Samples from these adjusted distances represent the pools in the plant data analysis.

Samples from source pools for comparison with created pools. The natural pools from which transplanting material was taken were of different sizes, and thus the complete data set on these pools had different numbers of samples for each pool. The most precise comparison of the source pools with the created pools for several statistical analyses required representing the source pool systems by 10 samples each year, making the sample sizes equivalent to those from each created pool. To achieve this, from each source pool (and the combined set of four small pools used as the source for system C) we randomly selected a single meter-point-sample from each of the eight collection zones shown in Fig. 1.2, and two additional meter-point-samples at random from the whole pool.

Quantitative and statistical methods. Using the statistical models presented in Chapter 1, we judged the success of created pools by several comparisons with source pools, specifically: (1) average relative cover of native wetland plants per sample; (2) average number of native wetland plant species per sample (richness); (3) average density of native wetland plants; (4) average height of native wetland plants; and (5) similarity of the species composition. The designation "wetland plant" included all species of FAC- or greater wetland affinity as given in Reed (1988). Native species are those designated as such in Hickman (1993). Relative cover for one species was its value expressed as a percentage of the total for all cover items measured, including bare ground and other non-living factors.

Average values for cover, richness and density have clear meanings-the amount each species contributes to an average is directly proportional to its abundance. For height, we used a single value for each species in the sample and then averaged those, so less abundant species contributed more to averages than more abundant ones. The variable still shows overall differences among samples, but needs to be interpreted with care. In discussing changes over time in source pools, we also utilized frequency, expressing this as the percentage all samples containing the item, as a means of gauging how widely spread the item was in the pools.

Statistical analysis was performed using DataDesk (Data Description, Inc., Ithaca, N.Y.). As stated in Chapter 1, differences were deemed significant if a multi-way analysis of variance for the factor in question had a p-value of .05 or less. Design of the experiment enabled us to evaluate "treatment" as the differences due to the inoculation methods in comparison with controls or source pools, "year," and "system," this latter for systematic differences among pool systems A, B, and C.

An additional analysis involved determining percent similarity of created pools with the source pools. In this method, one first calculates the percentage represented by each item within each of the two samples being compared, for example, cover of each plant species in a pool as a percentage of the total. For species shared between the two samples, the lower of the two percentage values for each shared species are summed. The index thus can range from zero, if no shared species occur, to 100, if all species represent the same percentages within each of the two samples. In this analysis, the set of all samples from the source pools was the standard for comparison, which provided a good method for determining if the randomly chosen set of 10 samples did, in fact, represent the source pools well.

Krebs (1989) pointed out that percent similarity does not have a statistical test for determining whether or not two samples being compared are "similar." In our analysis, however, the index was not used to determine similarity *per se*. Instead, we asked whether the means of sets of indexes, each index representing similarity of one of the replicated treatments to sources or controls, differed significantly. Each pool in each year is represented by one number. The distribution of these numbers can be assumed to be normally distributed and therefore subjected to testing with analysis of variance. The assumption is based on this logic:

> Repeated sampling of a given pool in a given year would produce a set of values of relative cover for each species. Although we produced just one sample each year, the assumption of normality needs to be examined in terms of how a set of values produced by repeated sampling would behave. The index of similarity is produced by species-by-species comparison among values for all shared species in two pools. Each value in the set can be assumed to vary continuously and be distributed in a normal, bell-shaped, fashion, since nearly all such ecological factors do. Examples would be the cover of a particular plant species or the density of a particular aquatic animal. The index of similarity sums up values (the smaller of the two percentages for the two pools being compared) each of which can be assumed to be normally distributed. A set of indices can be assumed to be normally distributed since each factor in the index is normally distributed.

Evaluation of fidelity of transplants to sources. An important question of the experiment is the degree to which the species that were seen in the inoculated pools were the result of the transplanting methods as opposed to having invaded the pools on their own. Comparison of inoculation treatments with the uninoculated controls is one way for judging this, but information on the species composition of inoculated pools in comparison with their respective sources can also be used. We did this latter comparison by first plotting the relative cover of each species in each system for: the sources (all samples) from 1993-96; the controls and Vac1 from 1994-96; and Vac2, Blocks, and Soil in 1995 and 1996. Such graphs appear in Appendix B. Graphs were then evaluated qualitatively for "source-fidelity" as follows:

High fidelity: The species occurs in inoculated pools and the source pools of the same pool systems, with very little or no occurrence in other created pools. There is little or no presence in the control pools.

Moderate fidelity: The species occurs largely in the same pool systems, but with moderate presence in inoculated pools of other systems. It may occur in moderate amounts in control pools. We assumed that presence in controls or in treatments not associated with the observed source was due to colonization from an unknown outside source.

Low fidelity: There was no clear relationship between the presence of the species in inoculated pools and its presence in the sources for those pools.

Not applicable: Fidelity as a concept does not apply because there was no presence in an inoculated pool.

Evaluation of fidelity in year-to-year trends. There were noticeable year-to-year trends in the source pools over four years of sampling. In a general way, the graphs of relative cover in Appendix B could be evaluated to determine if the created pools reflected these trends. Scores of high, moderate, low, and not applicable matches of this trend were made.

Success of treatments with respect to individual species. The graphs of species presence in pools in Appendix B were also scored for the degree of success that species demonstrated in 1996 in each inoculated pool. Categories were: "high," for instances were the relative cover of the species was approximately the same as or higher than that of the source pools; "good" for values more than 50% of the difference between low and high, but not at the high level; "fair" for values below this 50% level but with more than token presence; and "low" for cases where the species was just barely present. Using these ratings, we compared the different inoculation methods for overall success and from the standpoint of the different responses of species to them.

RESULTS

Changes in the spatial distribution and cover of plants in source pools. With the removal of disturbance due to our protective fencing, all of the source pools changed markedly in the nature of their plant communities over four years. The differences in management of the source pools prior to this study, in addition to floristic differences that may be from other prior causes, led pools to vary somewhat in how they changed over four years of monitoring. (See Appendix B for complete data and Chapter 1 for descriptions of the pools.)

The similarities and differences in the pools over the four years in which permanent transects were monitored showed up in a number of ways.

The frequency of bare ground decreased markedly in all source pools under the protection from disturbance necessary for this research (Fig. 2.9). The decrease was more marked in systems A and B than in system C, possibly because the uneven topography in the latter system due to past discing led to continued presence of bare ground on the sides of mounds of earth created by the discing. Fig. 2.9 indicates the percentages of samples that had some bare ground, not the amount of bare ground. For comparison, Fig. 2.10 shows absolute cover of bare ground each year, and shows the decrease from 1993 to 1994 after pools were protected.

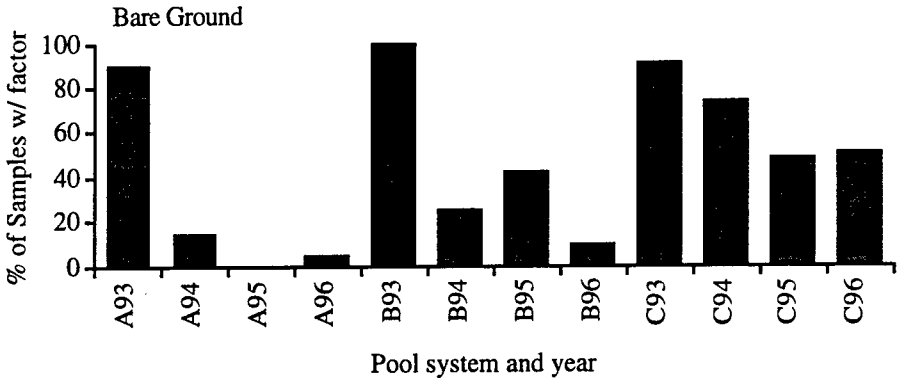

Figure 2.9. Frequency of bare ground in source pools over four years.

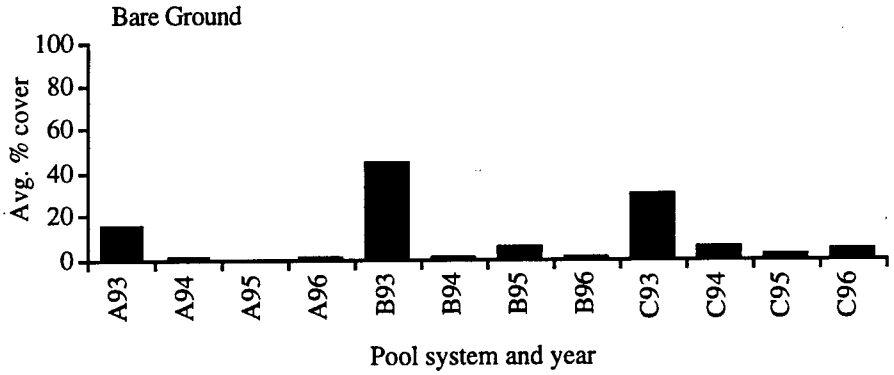

Figure 2.10. Average cover of bare ground in source pools over four years.

As the plant cover closed, some of the small, annual, native wetland species decreased in the extent of the pools in which they were found, as well as in cover. Examples of these frequency changes are shown in Fig. 2.11, and include *Veronica peregrina*, *Crassula aquatica*, *Callitriche sp.*, and *Juncus bufonius*. *Downingia concolor* is another small annual. It showed a similar pattern of continuous decline in cover, but frequency didn't change much. This abundant plant was still widespread, but decreasing in abundance. *Plagiobothrys stipitatus*

var. *micranthus* and *P. trachycarpa* both showed general patterns of decline, but peaked in cover in year 2.

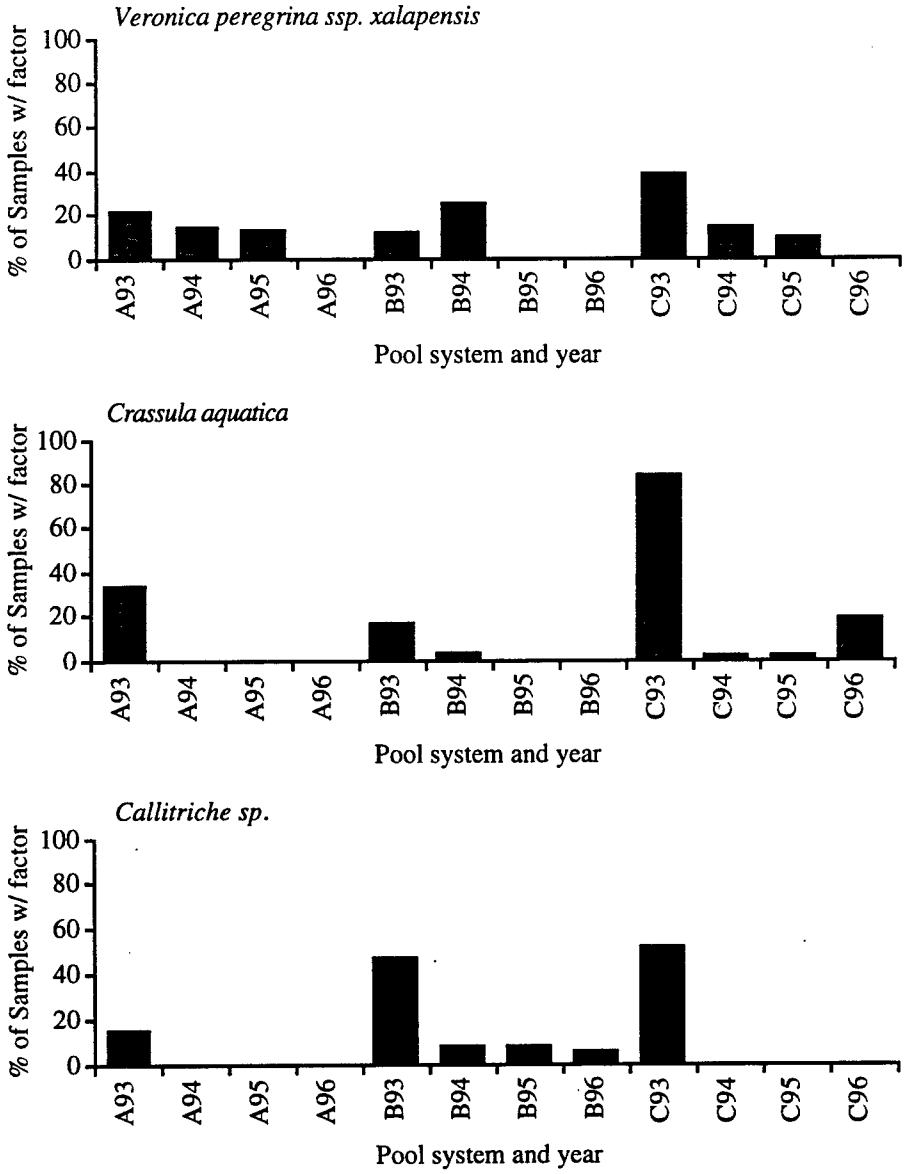

Figure 2.11. Examples of changes in frequency of native annual plants in source pools over four years. (continued next page)

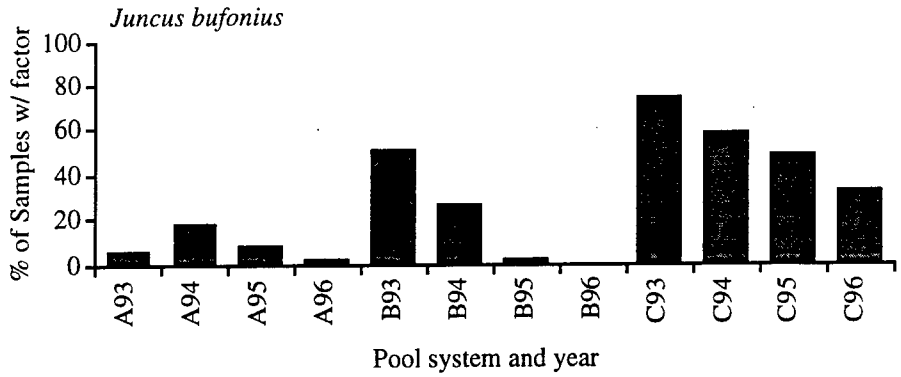

Figure 2.11. continued. Examples of changes in frequency of native annual plants in source pools over four years.

Several species increased in extent and cover during the four years. The most striking of these changes was the spread of the non-native annual grass, *Polypogon monspeliensis*, shown in Fig. 2.12. It was found in approximately 80% of all source pool samples in 1996, up from below 10% in 1993. Cover values increased from close to zero to 15-20% in all systems for this grass (not shown). A second non-native, the perennial *Rumex crispus* showed a similar trend. This tall plant had its highest cover value of 11.7% in the source pool of system A in 1996.

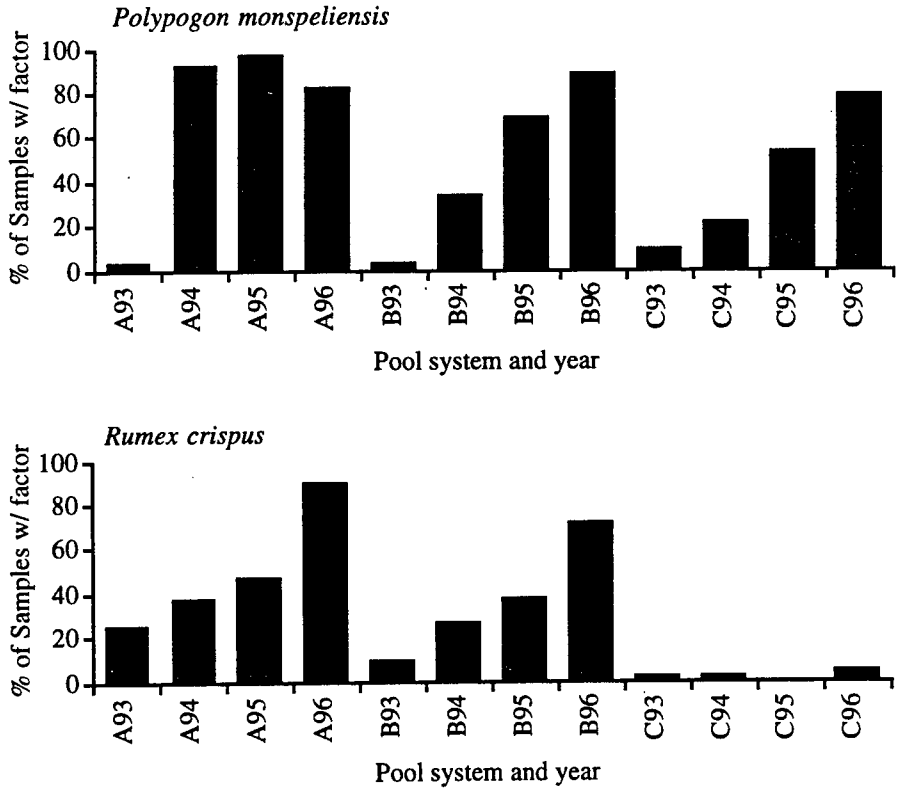

Figure 2.12. Frequency of two non-native plants in source pools over four years.

Several species increased in source pools of one system and not in another. Some of these were not found in a given system. Examples (Fig. 2.13) include the native perennial *Eryngium aristulatum* (systems A and C), the native annual *Pleuropogon californicus* (increase primarily in system B, absent from A), and the native annual grass, *Deschampsia danthonioides* (near absence in A, increase only in C).

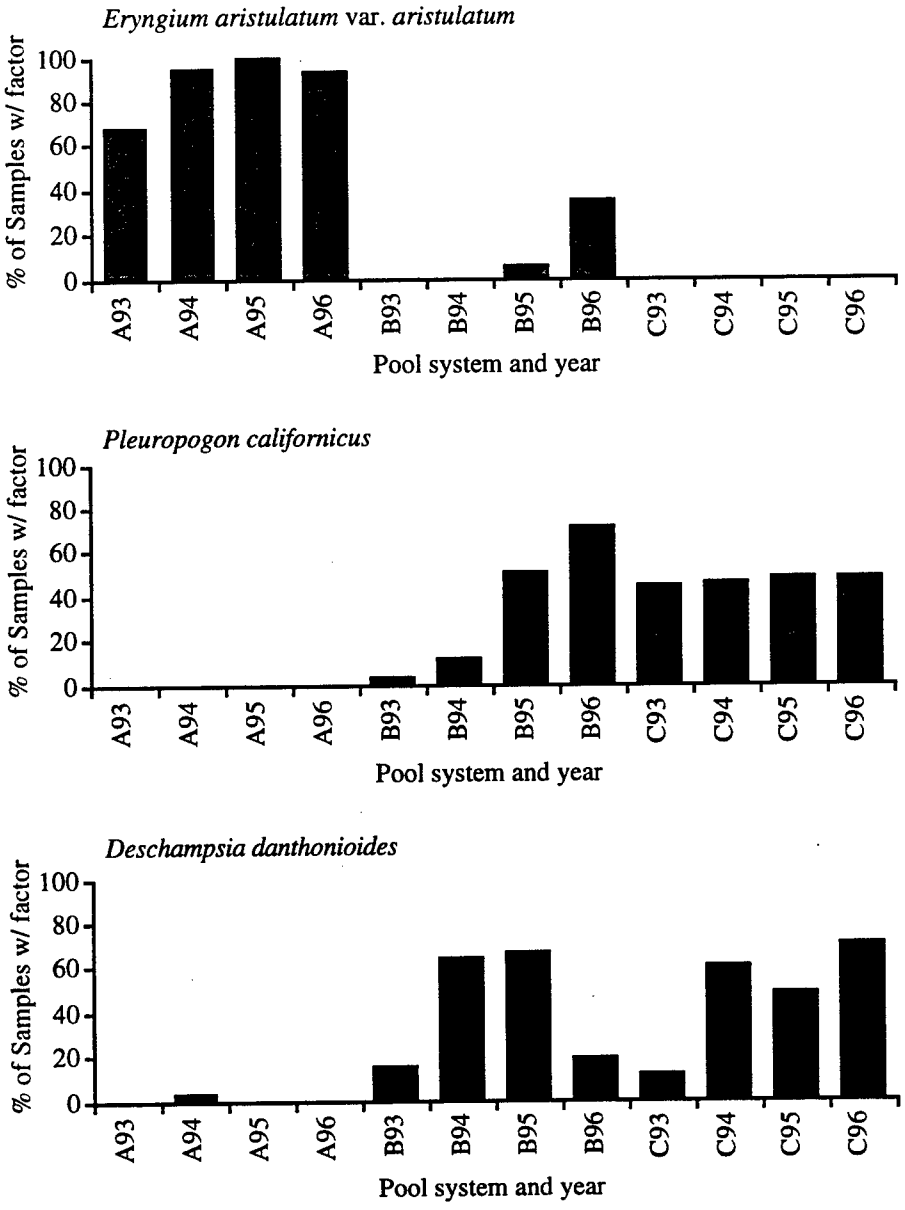

Figure 2.13. Examples of changes in frequency of three native plants in source pools over four years.

Plants that increased tended to be tall and/or perennial. Along with a general loss of native annuals and an increase in the stature of the plants was an increase in both the frequency of plots containing thatch (the dead but not fully decomposed plant matter lying on the surface of the soil) and its cover (Fig. 2.14). Cover values for this factor do not appear alarmingly high in 1996, but the rate of increase in the factor over four years will have important affects on the community. Such thatch interferes with early growth of a number of plants, particularly small annuals.

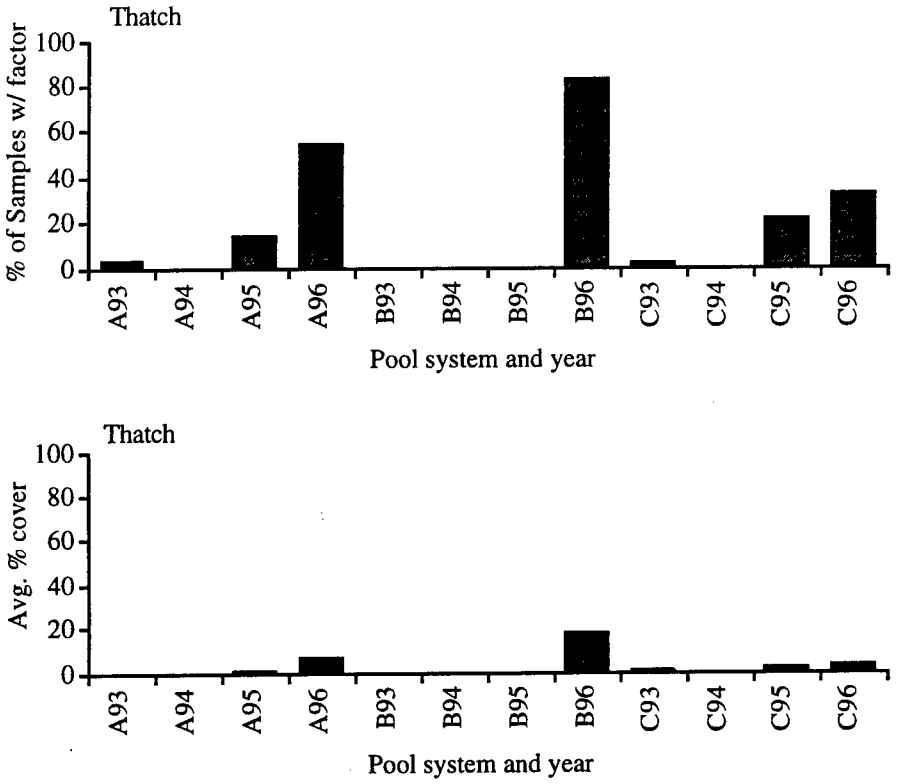

Figure 2.14. Change in frequency and cover of thatch in source pools over four years.

Collectively, these changes in the nature of the plant community show how great the affect of disturbance is on the nature of plant communities in the study zone. All of the source pools were disturbed prior to the study, so one cannot necessarily generalize to all regions of California, but the data show that measurement of success in created pools in comparison with source pools is highly dependent on the nature of the disturbance regime to which the pools are subjected. The concept of being "self sustaining" for our created pools cannot be one in which the pools should be expected to maintain diversity under complete protection, since the natural pools of our study area did not do so.

Qualitative evaluation of success of species in the three treatments. Here we examine the number and type of species that perpetuated themselves in the created pools into 1996. Each of the native and non-native wetland species that was present in one or more source pools was evaluated for success using species graphs of relative cover in Appendix B and comparing performance of the species in inoculated pools in 1996 (Vac2, Blocks, and Soil only) with values of their respective source pools in 1994, the year materials were taken for inoculation.

Fig. 2.15 reproduces two graphs from the appendix as examples. *Lasthenia glaberrima* was highly successful in all inoculation treatments. It occurred almost exclusively in sources for systems A (black bars) and B (white). In year 2 treatments (Vac2, Blocks, and Soil for

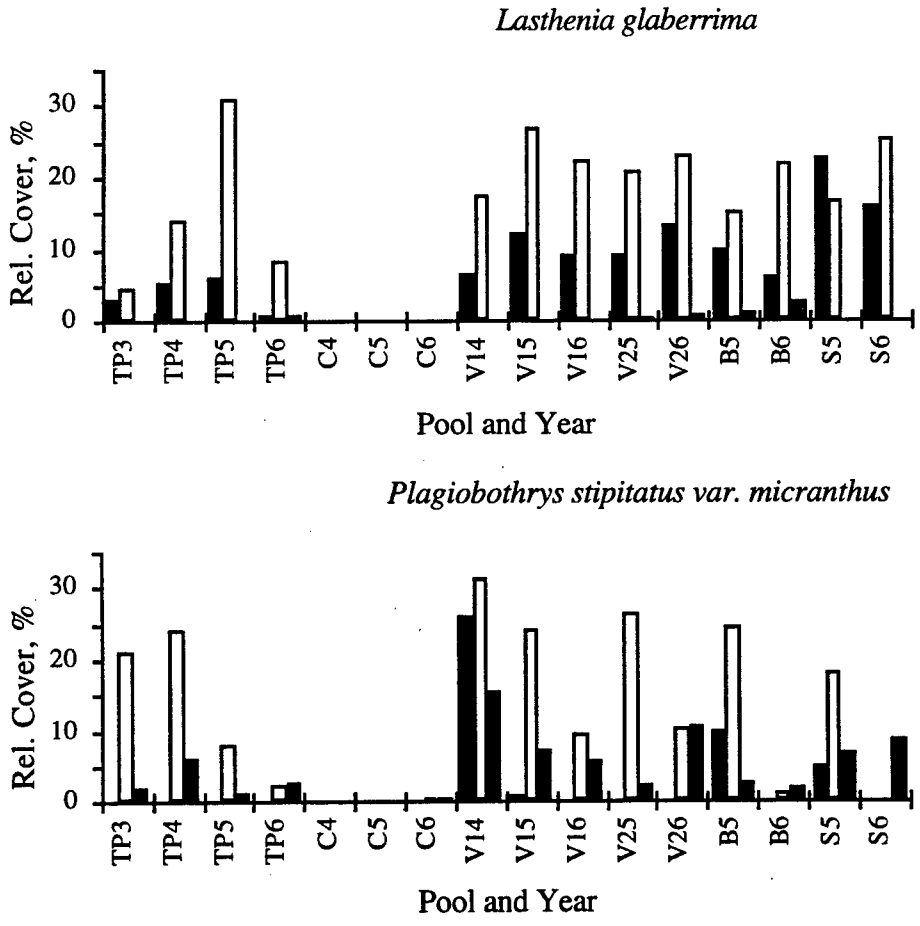

Figure 2.15. Examples of changes in relative cover for two species in source pools (TP, standing for "total pool," derived from all samples), controls (C), Vac1 (V1), Vac2 (V2), Blocks (B) and Soil (S). Years 1993-1996 are abbreviated with the numbers 3-6. Black bars represent pool system A, white bars B, and gray bars C. Figures for all species appear in Appendix B.

1996) relative cover values were equivalent or higher than sources for all treatments. By contrast, *Plagiobothrys stipitatus* var. *micranthus* ranked high in Vac2 because it did better in system C (gray bars for V26, "Vac2, year 1996") than sources (gray TP6 for "total pool 1996") and approximately half as well in system B (white V26 compared with white TP4). It appeared in source pools only in these two systems. In Soil, it did well in system C but not B, rating fair, while it had low success in blocks in the two systems.

Table 2.1 summarizes the results of this evaluation. Twenty-one of the native wetland species from the source pools persisted at some level in the inoculated pools into 1996. Three natives with low relative cover in source pools did not appear in inoculated pools, or appeared only in 1995: *Callitriche sp.*, *Veronica peregrina* ssp. *xalapensis*, and *Trifolium depauperatum* var. *truncatum*.. The same is true for four non-natives: *Vulpia bromoides*, *Poa annua*, *Plantago lanceolata*, and *Ranunculus muricatus*. Overall, 16 of 24 native wetland plants had "good" or "high" ratings in at least one inoculated pool. Three had at least one "fair" rating but no "goods" or "highs." Two species from sources had low ratings. Among non-natives, seven of 13 species in source pools had at least one good or high rating. Two were present in second year treatments with low success, while four that had very low relative cover values in source pools did not appear in inoculated pools in 1996.

Success for the upland species found in source samples is shown graphically in Fig. 2.16. The treatments are essentially equivalent in terms of their ability to exclude upland species, although a few more of these survived in Blocks than in Soil, and Vac2 was best in this regard.

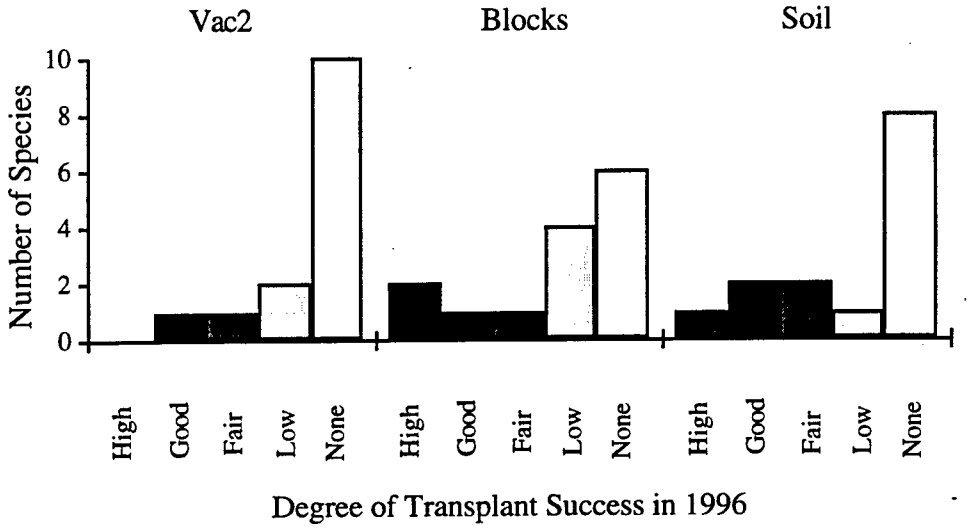

Figure 2.16. Success in 1996 of transplanted upland species in the three inoculation treatments.

Table 2.1. Success in 1996 of wetland species, grouped according to inoculation treatments where such success was highest.

Scientific Name	Native	Wetland Type	Success in 1996 Vac2	Blocks	Soil
1. Good to High Success in All Treatments					
Lasthenia glaberrima	yes	OBL	high	high	high
Eryngium aristulatum var. aristulatum	yes	OBL	high	high	high
Pilularia americana	yes	OBL	high	high	high
Plagiobothrys trachycarpus	yes	FACW*	good	high	good
Psilocarphus brevissimus var. multiflorus	yes	OBL	high	good	good
Polygonum arenastrum	no	FAC	good	good	good
2. Good to High Success in Vac2 & Blocks					
Downingia concolor	yes	OBL	high	high	good
Xanthium strumarium	yes	FAC+	high	good	fair
3. Notably Higher Success in Vac2					
Plagiobothrys stipitatus var. micranthus	yes	OBL	high	low	fair
Hemizonia pungens	yes	FAC	high	low	low
Crassula aquatica	yes	OBL	fair	none	low
4. Good to High Success in Blocks &Soil					
Polypogon monspeliensis	no	FACW*	fair	high	high
Pleuropogon californicus	yes	OBL	low	high	high
Briza minor	no	FACW-	none	good	high
Juncus bufonius	yes	OBL	low	good	good
Lythrum hyssopifolium	no	FACW	low	good	good
Lolium multiflorum	no	FAC	none	good	good
5. Notably Higher Success in Blocks					
Cotula coronopifolia	no	FACW+	fair	high	fair
Lilaea scilloides	yes	OBL	low	high	fair
Hemizonia parryi	yes	FAC	none	high	fair
Hordeum marinum ssp. gussoneanum	no	FAC	none	good	low
Achyrachaena mollis	yes	FAC	none	good	low
6. Notably Higher Success in Soil					
Deschampsia danthonioides	yes	FACW	low	fair	good
Alopecurus saccatus	yes	OBL	low	fair	good
Eleocharis macrostachya	yes	OBL	low	none	fair
Lasthenia conjugens	yes	FACW	none	none	fair
7. Present at Low Level in All Treatments					
Rumex crispus	no	FACW	low	low	low
8. Present at Low Level in Vac2 and Soil					
Plagiobothrys greenei	yes	FACW	low	none	low
9. Present at Low Level Only in Soil					
Picris echioides	no	FAC*	none	none	low
Navarretia intertexta ssp. intertexta	yes	OBL	none	none	low

Colonization of the control pools. Two native species have values for relative cover in the control pools that approach or exceed values in other pools-*Juncus bufonius* and *Psilocarphus brevissimus* var. *multiflorus* (Appendix B). In addition, these pools have been very strongly invaded by the non-natives *Lythrum hyssopifolium* in winter and early spring

and *Convolvulus arvensis* in early summer. The non-native wetland grass *Lolium multiflorum* has done well in the control pool of system C. The ability of these uninoculated pools to eventually develop significant native plant species compositions is not clear.

In summary, the success of native wetland plants in the inoculated pools was good. Some of the plants that have declined in sources have retained higher relative cover values in inoculated pools.

Fidelity of the species composition of created pools to that of sources, and correspondence to year to year trends. An important means of gauging the success of the transplanting techniques is to examine the degree to which presence of individual species in treatment areas corresponds to the presence of these same species in source pools, which we defined in methods as source-fidelity. Trend-fidelity is seen when a species decreases or increases from year to year in created pools in a manner matching that of source pools. Appendix B summarizes the relative cover values for each pool system over all years.

As examples of these judgments, *Lasthenia glaberrima* in Fig. 2.15 above was highly source-faithful because it was nearly limited in created pools to those in systems whose source pools contained it. *Plagiobothrys stipitatus* var. *micranthus* was moderately source-faithful because created pools contained it in systems where sources also did, but it appeared as well in the created pools of the third system. *L. glaberrima* was moderately trend-faithful because most created pools reflected the drop from 1995 to 1996 seen in sources, but less dramatically than sources. *P. s. micranthus* was highly trend-faithful. It declined from 1995 to 1996 as it did in source pools in system B (white bars), and in two of the four treatments it increased in these years as did sources in system C (gray bars).

Table 2.2 shows information for source-fidelity and trend-fidelity for the most common wetland plants, those having ≥5% relative cover in at least one source area in at least one year. These species were moderately to highly source-faithful in a large number of cases. Of the 13 natives (top of Table 2.2) in this high-cover group, all were moderately to highly source faithful. Of wetland non-natives (middle of Table 2.2), 6 of 7 were moderately to highly source-faithful.

Table 2.2. Response in inoculated pools of species with greater than 5% relative cover in one or more source pool systems (all samples) in one or more of the years 1993-96. Species are grouped in descending order of maximum source-pool cover as wetland natives, wetland non-natives, and upland plants (native and non-native combined). [For this table and Table 2.3, Wetland Types come from Reed (1988) with species not given designations listed here as UPL=Upland plants. FAC, FACW, and OBL indicate wetland species; FACU, NI, and UPL indicate upland plants. "Out" under the heading "Sources In" means that the species appeared in created pools but not the source for their system. For treatments: V1=Vac1, V2=Vac2, B=Blocks, and S=Soil.]

Scientific Name	Native	Wetland Type	Source Faithful	Trend Faithful	Sources In	Max. Cover	Best Treatment	Best Year
Plagiobothrys trachycarpus	yes	FACW*	high	mod	A C B	32.65	V2 B S	95
Lasthenia glaberrima	yes	OBL	high	mod	B A C	30.75	V1 V2 B S	96
Pleuropogon californicus	yes	OBL	mod	high	C B Out	30.48	S B	96
Plagiobothrys stipitatus var. micranthus	yes	OBL	mod	high	B C Out	24.32	V2 V1 S	94 95
Eryngium aristulatum var. aristulatum	yes	OBL	high	high	A B	22.09	V1 V2 B S	96
Downingia concolor	yes	OBL	high	mod	A B C	21.9	V1 V2	95
Eleocharis macrostachya	yes	OBL	high	low	A	13.76	S	96
Deschampsia danthonioides	yes	FACW	high	high	B C	11.63	S	95
Juncus bufonius	yes	OBL	mod	mod	C B A	10.17	V1 S	95
Lilaea scilloides	yes	OBL	mod	high	B C Out	8.07	B S V1	96
Pilularia americana	yes	OBL	mod	high	B C	6.92	V1 V2 B S	96
Crassula aquatica	yes	OBL	high	low	A B C Out	6.61	V1 V2	96
Hemizonia parryi	yes	FAC	high	high	C	5.6	B S V1	95
Polypogon monspeliensis	no	FACW*	mod	high	A B C Out	19	B S	96
Hordeum marinum ssp. gussoneanum	no	FAC	mod	low	A B C	18.4	B	96
Cotula coronopifolia	no	FACW+	high	mod	A B C	15.15	V2 B	95 96
Lolium multiflorum	no	FAC	high	mod	C A B	10.91	B S	96
Rumex crispus	no	FACW	low	low	A B Out	7.74	na	na
Lythrum hyssopifolium	no	FACW	mod	mod	C B A Out	6.16	V1 S B	95
Picris echioides	no	FAC*	high	low	B	5.22	S	96
Eremocarpus setigerus	yes	UPL	high	high	A C B	7.84	V2 B S	95
Erodium botrys	no	UPL	high	mod	C B A	7.68	V1	94
Centaurea calcitrapa	no	UPL	na	na	A B C	6.36	na	94

Of the three upland plants in this high-cover group (bottom of Table 2.2), one, *Eremocarpus setigerus* is a native that often invades open spaces in vernal pools in the dry season. It was highly source faithful, as was *Erodium botrys*. Viewed strictly in terms of the efficacy of the transplanting methods, 21 of the 22 of all species in Table 7 for which a judgment could be made (excludes *Centaurea calcitrapa*) were source-faithful at moderate to high levels. Seventeen of 22 were trend-faithful.

Table 2.3 presents equivalent information on species that had relative cover values greater than 1% but less than 5% in at least one source area in at least one year. Of five native wetland species in this group for which judgments could be made (top of the table), four ranked moderate to high in source fidelity. *Psilocarphus brevissimus var. multiflorus*, ranked low in source-fidelity because it has invaded control pools as well as inoculated pools beyond system B, its only source area. Three of the five natives were moderately trend-faithful.

Table 2.3. Response in inoculated pools of species with greater than 1% but less than 5% relative cover in one or more source pool systems (all samples) in one or more of the years 1993-96. Species are grouped in descending order of maximum source pool cover as wetland natives, wetland non-natives, and upland plants (native and non-native combined). [See legend of Table 7 for additional details.]

Scientific Name	Native	Wetland Type	Source Faithful	Trend Faithful	Sources In	Max. Cover	Best Treatment	Best Year
Hemizonia pungens	yes	FAC	mod	low	A B Out	4.48	V1 V2.B	96
Alopecurus saccatus	yes	OBL	mod	mod	B C	3.71	B S	96
Xanthium strumarium	yes	FAC+	high	mod	A	2.71	V1 V2 B S	95
Callitriche marginata	yes	OBL	na	none	A B C	2.14	na	93
Navarretia intertexta ssp. intertexta	yes	OBL	high	mod	C	1.17	V1 S	95
Psilocarphus brevissimus var. multiflorus	yes	OBL	low	low	B Out	1.06	V1 V2 S B	96
Polygonum arenastrum	no	FAC	low	mod	A B C	3.47	V2 B S	96
Briza minor	no	FACW-	high	high	C	1.65	V1 B S	96
Vulpia bromoides	no	FACW	mod	high	A C	1.34	V1	95
Poa annua	no	FACW	mod	low	B C	1.03	B S	95
Centaurea solstitialis	no	UPL	low	low	A C	3.12	V1	94
Convolvulus arvensis	no	UPL	mod	mod	A B C Out	2.26	V1 V2	95
Medicago polymorpha	no	UPL	high	high	BC	1.9	V1 B S	94
Spergula arvensis ssp. arvensis	no	UPL	high	high	C	1.7	V1 B S	95
Hypochaeris glabra	no	UPL	high	mod	C A	1.5	S B	96
Cuscuta howelliana	yes	UPL	high	high	A	1.28	V1	95
Avena sativa	no	UPL	na	na	C	1.06	na	na

Of the four non-native wetland plants in the middle of Table 2.3, three were moderate or high in source-fidelity and trend-fidelity. The remaining seven plant species in Table 2.3 are upland plants, and judgments could be made on all but *Avena sativa*. One of these that was rated high in source-fidelity as well trend-fidelity, *Cuscuta howelliana*, is actually a native parasite of genera like *Eryngium*. This plant is watch-listed by the California Native Plant Society (Skinner and Pavlik 1994), and its success in the treatment pools is desirable. One of the other six, *Convolvulus arvensis*, invades pools in summer and was rated moderately source-faithful; a similar pattern was seen for *Hypochaeris glabra*. Overall, five of six of these upland species were moderately to highly faithful to the sources and trends.

For species in both Tables 2.2 and 2.3 combined, 33 of 37 were moderately to highly source-faithful and 28 of 37 were trend-faithful. Plants in the treatment pools were clearly there largely as a result of the inoculation, and most followed year-to-year trends seen in the source pools.

Planting in the year of pool creation or one year later. The prediction of this analysis was that pools receiving the same treatment in year 2 should outperform those inoculated in year 1 because of erosion or other factors in year 1. Many vernal pool natives grow submerged in water early in the season, and higher turbidity could decrease photosynthesis. Comparison for this analysis would involve looking at each pool type in its first and second years following inoculation. Year 1 following pool construction was a below-average rainfall year (the 1993-94 wet season), but year 2 was an extremely wet one (see data in Appendix A. Because of the radically different amounts of rainfall in the two years, any effect of "year" as a separate factor cannot be unambiguously evaluated.

Keeping this qualification in mind, we compared Vac1 and Vac2 through their first two years. All statistical comparisons for treatments alone were for Vac1 in 1994 and 1995 and Vac2 in 1995 and 1996. Values for the source pools (based on 10 samples per pool) in the years of inoculation and for controls in all years are shown for comparison. These source pool and control values were also included separately with the values for inoculated pools in sets of variables for statistical tests.

There was no significant difference between Vac1 and Vac2 in relative cover of native wetland plants (Fig. 2.17), but analysis of variance including all controls with Vac1 and Vac2 through two years showed a significant treatment effect ($p \leq .0001$). The figure clearly shows that this is due to there being very low cover values in controls. The effect of "year" was significant when controls were included ($p=.0410$) as was "system" ($p=.0366$).

A test for the set including only source samples and the two inoculation treatments produced no significant result. Notably, both methods have produced immediately successful results comparable with sources, and Vac1 performed well three years after inoculation. Graphs and statistical results for all wetland plants and for native annual wetland plants were very similar, and are not shown.

Average values of absolute cover for the samples are shown at the top of Fig. 2.17. Vac1 was lower than the source sample (93Source) in its first year, rose to a higher value than sources in the second year and then declined. Vac 2 also declined in year 2, but values for both treatments remained high in comparison with controls.

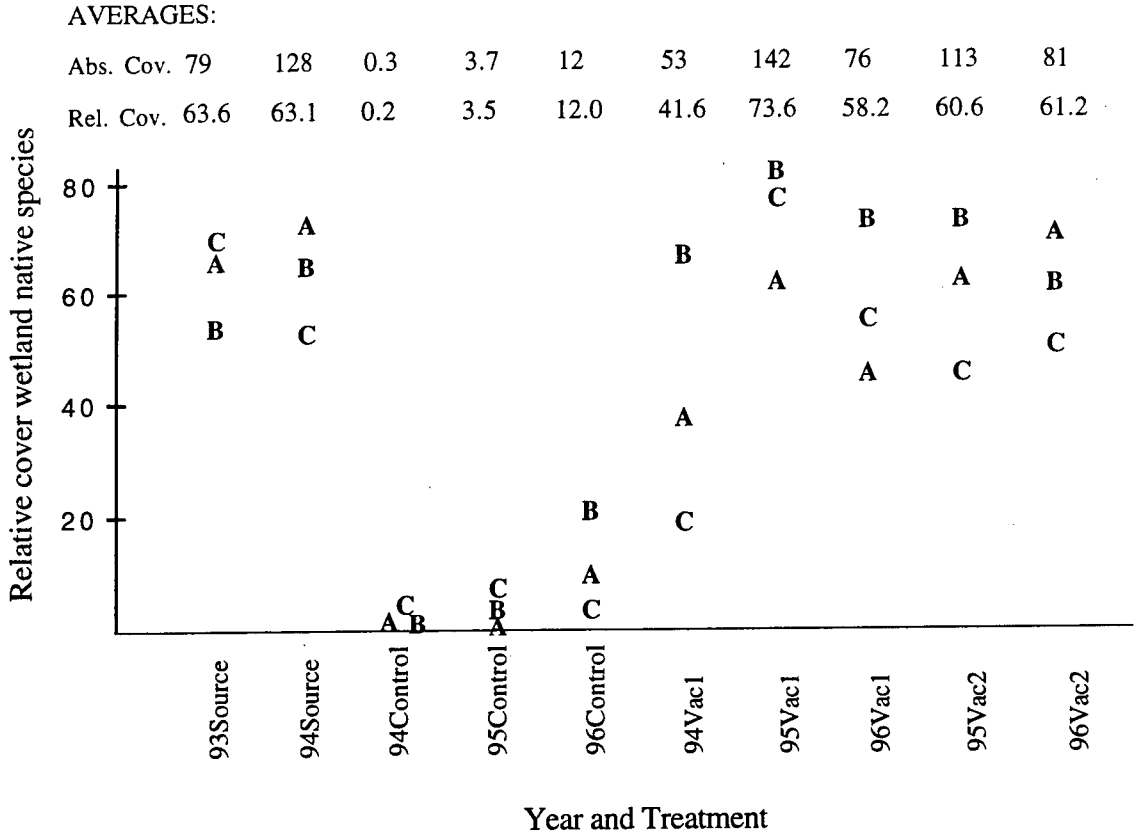

Figure 2.17. Comparison of source, control, Vac1, and Vac2 treatments in relative cover of native wetland plants. Values for pools in each system are plotted with their respective letters: A, B, and C.

In a second measure of success, the average number of native wetland plant species per sample (Fig. 2.18), the two methods also did not differ significantly, but showed a significant effect of "system" (p=.0136). The higher numbers of species per sample in system C and lower numbers in system A account for this effect.

In a comparison of inoculated pools with sources (Fig. 2.18) the values of created pools were higher, but the effect was not statistically significant. There was a significant effect of "system" (p=.0156), for reasons given in the previous paragraph. The number of native wetland species per sample was significantly higher in inoculated pools than in the controls ($p \leq .0001$).

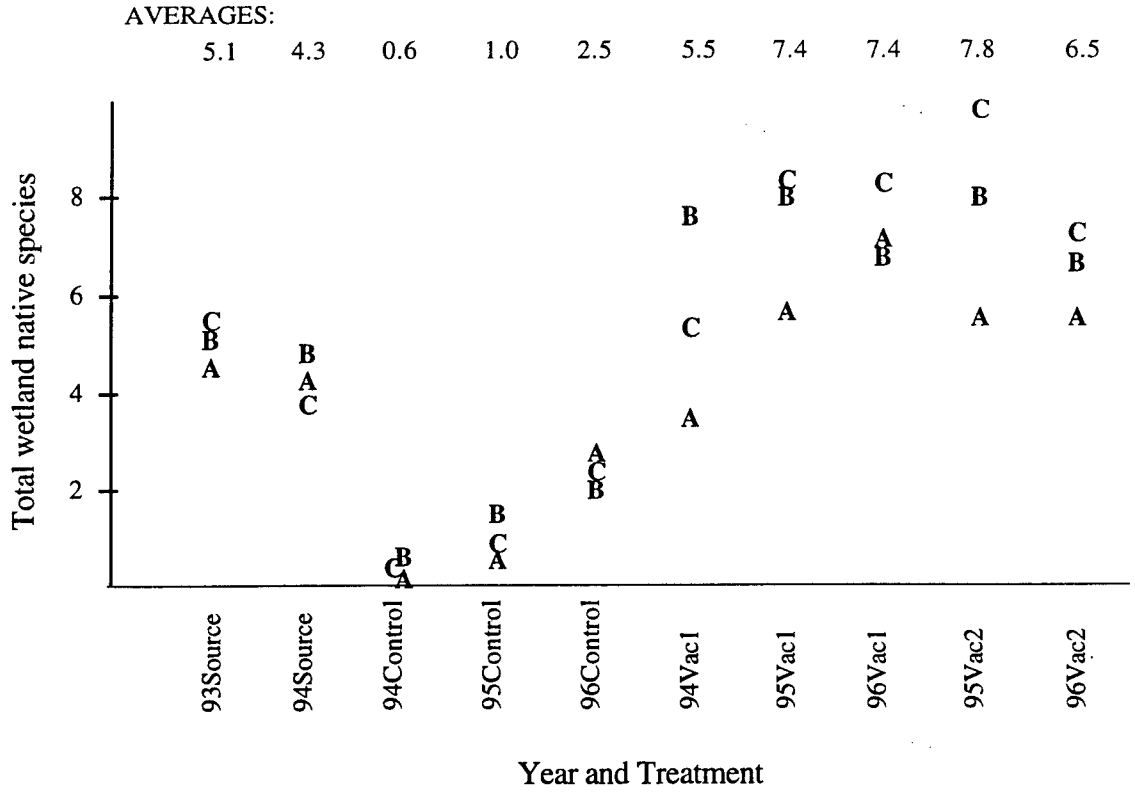

Figure 2.18. Comparison of source, control, Vac1, and Vac2 treatments in richness of native wetland plant species per sample. Values for pools in each system are plotted with their respective letters: A, B, and C.

Average densities in the pools are shown in Fig. 2.19, and ranged from near zero in controls in their first two years to above 2,000 plants/m^2 in system A source pools in 1994. In examining density, it is important to remember that some species will contribute greatly to the values (for example *Downingia concolor*), while others with equivalent or sometimes higher cover contribute little (*Eryngium aristulatum* var. *aristulatum*). Vac1 and Vac2 did not differ significantly in density, but both declined in their respective years two to values equivalent to those in source pools in the first year. These inoculation treatments were significantly higher than controls (p=..0005), but did not differ significantly from sources.

The great increase in density in source pools in 1994 is doubtless due to their release from moderately heavy disturbance combined with good success of smaller annuals in this second year. Density declines in inoculated pools could be a result of exhaustion of the seed bank contributed in inoculation or to increasing competition for space among larger plants. Since average height didn't change much (Fig. 2.20), this latter effect is unlikely.

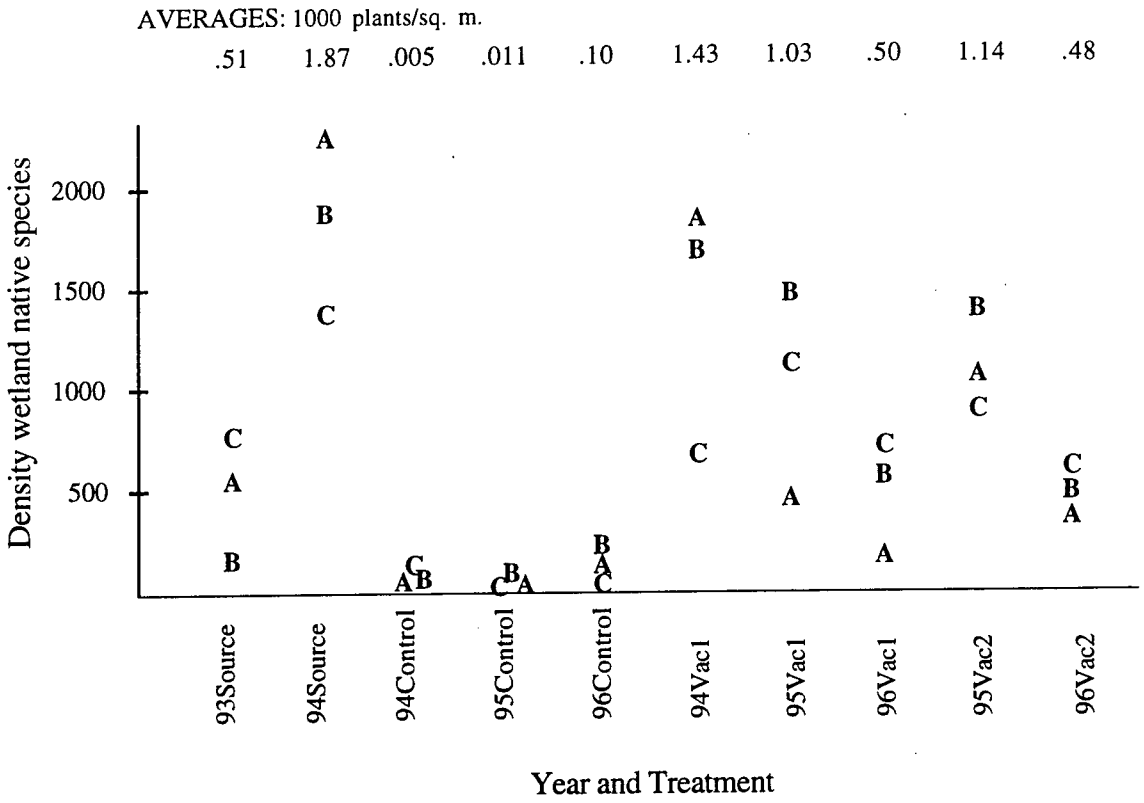

Figure 2.19. Comparison of source, control, Vac1, and Vac2 treatments in average density (plants/m^2) of native wetland plant species. Values for pools in each system are plotted with their respective letters: A, B, and C.

Average heights of native wetland plants did not differ among inoculation treatments themselves, although there was a significant effect of year (p=.0336). Values increased from year 1 to 2 in Vac1, and declined slightly on average in Vac2. There were significant effects of treatment when controls were included (p=.0004), with inoculated pools having higher values. There was also an effect of year in this set (p=.0119). The much higher values for sources in the second year led to there being a significant treatment effect when sources and Vac1/Vac2 in their first two years were included in the set for analysis (p=.0004), and "year" had a strong effect in this set (p=.0119).

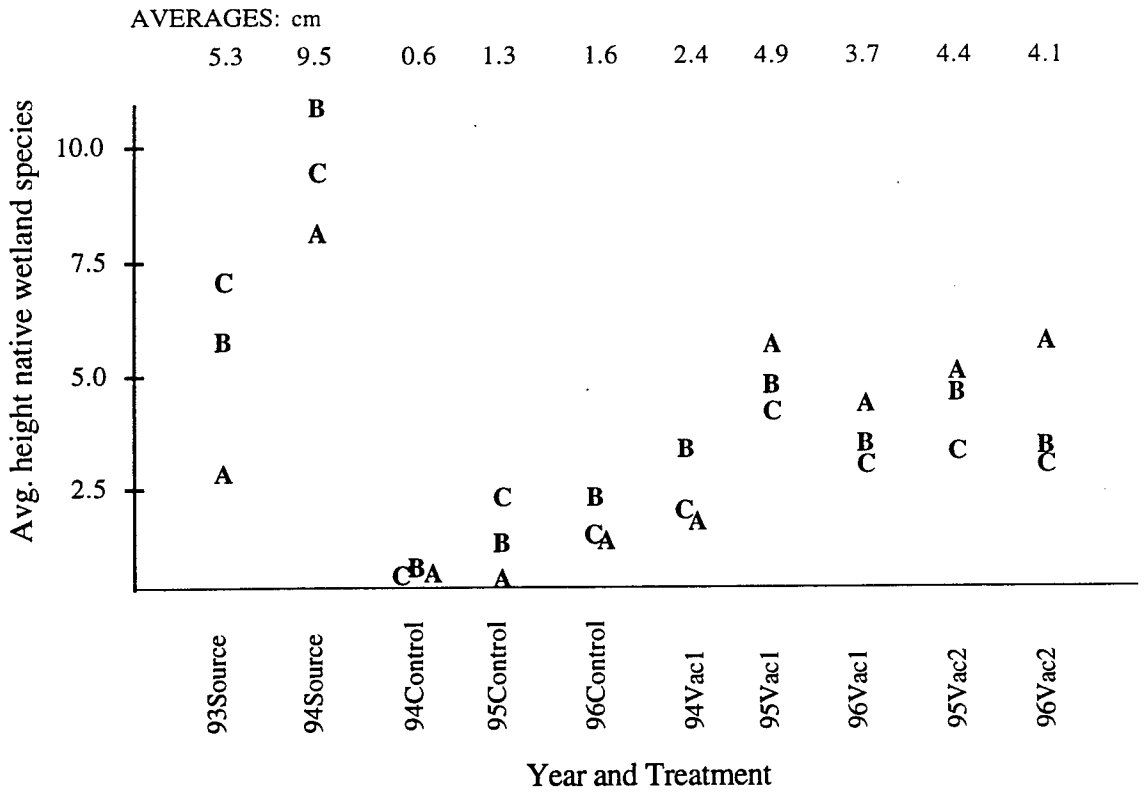

Figure 2.20. Comparison of source, control, Vac1, and Vac2 treatments in average height (cm) of native wetland plant species. Values for pools in each system are plotted with their respective letters: A, B, and C.

Evaluation of four measures of comparison showed the Vac1 and Vac2 pools to perform equivalently in their first two years. For native wetland plants, they had lower average densities and heights than source pools, but the number of species per sample and relative cover did not differ significantly. Controls increased in all measures over three years, but continued to have significantly lower values than inoculated pools. This increase indicates, however, that pools with some component of native plants are likely to result in the long run as these controls develop further.

Effect of different transplant methods on the success of created pools. For this analysis, only the treatments transplanted from the source pool systems in the same year, 1994, were considered. The treatments include Vac2, Blocks, and Soil. In Blocks, the planting method yielded strips of planted and unplanted soil. Samples for pools receiving this treatment were always taken entirely within the planted strips, which occasionally required that the sampling device be turned at an angle. We also sampled these pools without adjusting the device, resulting in inclusion of some unplanted zone in the samples. In all cases, this method simply yielded values a small amount lower than the Blocks itself, and values are not reported here.

In relative cover of native wetland plants, all inoculation treatments had values higher than or equivalent to those of 1994 source samples (Fig. 2.21). Among the inoculated pools alone, the treatment effect was significant (p=.0108), for which the higher values for Soil are an obvious contributing factor. The set including controls plus inoculated pools showed a significant treatment effect (p≤.0001) due to the much higher values of all inoculated pools. The figure also shows the decline in native plants in source pools discussed above. Indeed, relative cover of native wetland plants was higher in all inoculated pools than sources in 1996 (p=.0003 for treatment in a set of sources and inoculated pools). None of the tested sets of variables showed significant effects for "year" or "system."

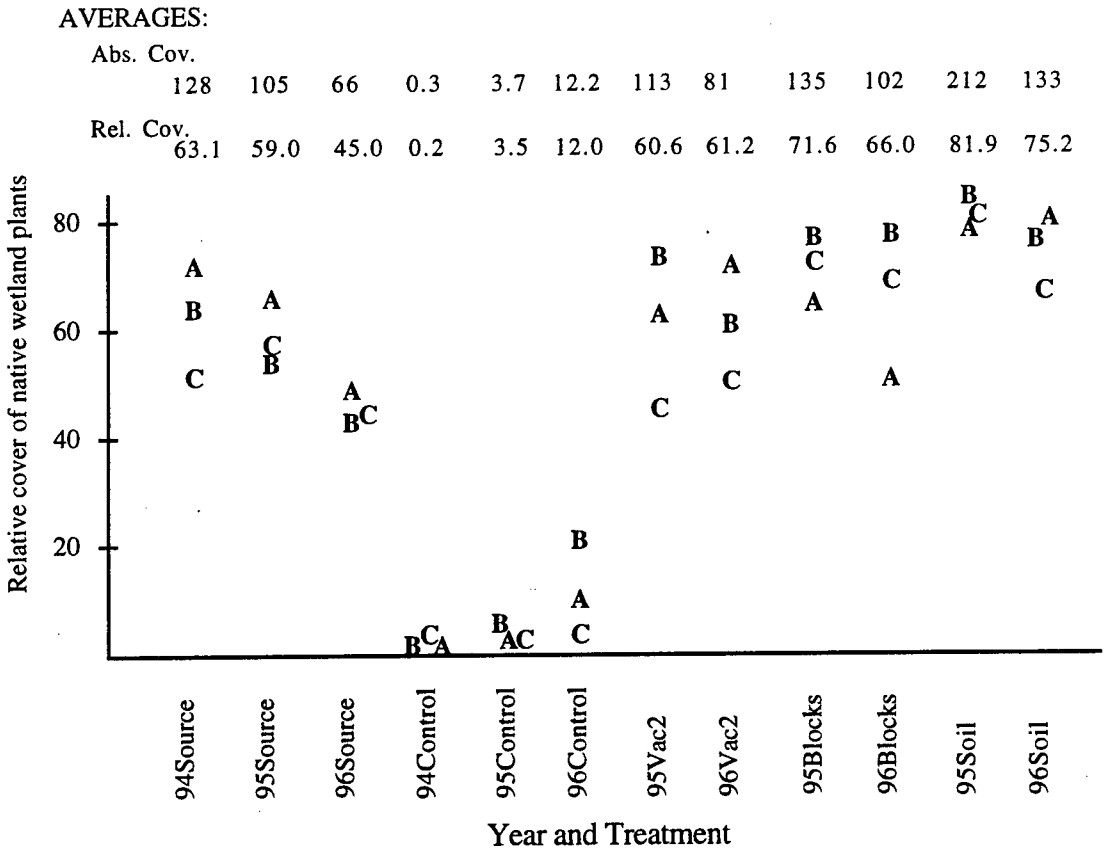

Figure 2.21. Comparison of treatments in relative cover of native wetland plants per sample (percent of total cover). Values for absolute cover are shown at the top for comparison. Values for pools in each system are plotted with their respective letters: A, B, and C.

In the source pools, the values of relative cover of all wetland plants have remained high (Table 2.4). Cover of native annual wetland plants has decreased in source samples markedly, but much less so in inoculated pools. All cover values have increased in the uninoculated controls.

Table 2.4. Relative cover for three categories of plants.

Group	All wetland species	Native wetland species	Native wetland annuals
94 Source	85.0	63.1	58.4
95 Source	95.1	59.0	49.3
96 Source	80.2	45.0	32.3
94 Control	1.1	0.2	0.2
95 Control	11.5	3.5	3.5
96 Control	26.2	12.0	11.6
95 Vac2	84.2	60.6	59.6
96 Vac2	69.1	61.2	51.9
95 Blocks	91.7	71.6	67.0
96 Blocks	89.6	66.0	57.1
95 Soil	96.5	81.9	80.6
96 Soil	90.9	75.2	65.3

In richness, measured as the number of native wetland plant species per sample (Fig. 2.22), the inoculated pools had significantly higher species richness than the source pools from the transplant year and the subsequent two years ($p \leq 0001$). The values also differed significantly between inoculated pools and controls ($p \leq .0001$), but there was no significant difference among inoculation treatments. The higher number of species per sample in inoculated pools may be due to the mixing of seeds from several portions of source pools during inoculation for Vac2 and Soil. Each small plot had a high number of species in year 1 and the number could be dropping as some species outcompete others. The same explanation could apply to Blocks, because the created pool bottoms had blocks from separated samples placed next to each other in several places. In all sets tested for richness, there were significant effects of "year" and "system," reflecting systematic changes from year to year and generally lower values for system A and higher ones for C.

At the top of Fig. 2.22, the average numbers of native wetland species for pools as a whole are given, and sources are slightly higher on average for this variable. It is notable, however, that the values in inoculated pools approach those of the sources, despite the smaller size of the inoculated pools. Both numbers of native wetland species per sample and number

per pool dropped between 1995 and 1996 for source and inoculated pools, but values continued to rise in controls.

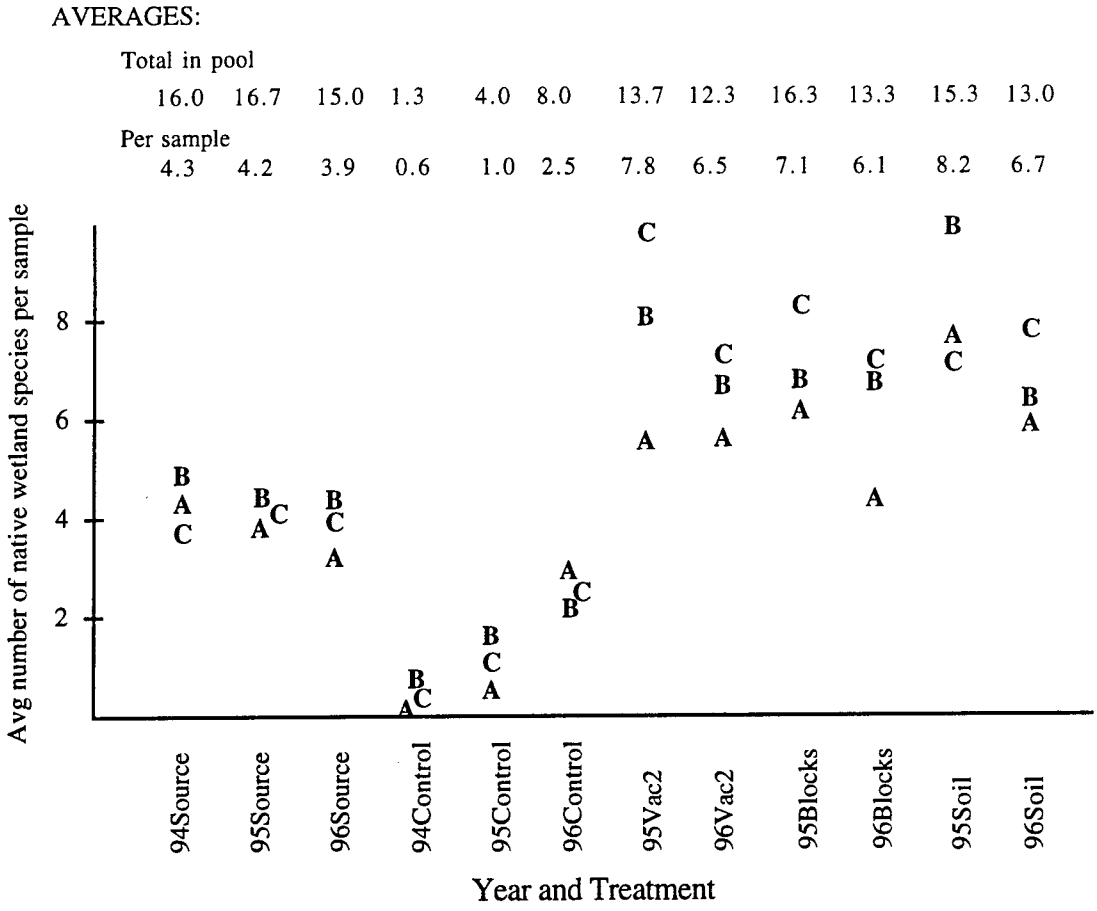

Figure 2.22. Comparison of treatments in richness of native wetland plant species per sample. Average native wetland species per pool are shown at the top for comparison. Values for pools in each system are plotted with their respective letters: A, B, and C.

In the previous section, we noted the dramatic rise in density of native wetland plants in the source pools from 1993 to 1994 (Fig. 2.19). As Fig. 2.23 shows, however, this sharp rise the year following protection of pools was followed by a sharp decline in 1995 that continued into 1996. Density in control pools increased very slightly over three years. In inoculated pools, initial density was notably higher in Vac2 than in other treatments, but was highest in Soil by year 2. Analysis of variance among inoculated pools themselves and in a set containing source pools as well did not show significant values for treatment, but there was a significant effect of year in the latter set ($p=.0185$). The analysis on the set of controls plus inoculated pools showed a significant treatment effect ($p=.0007$) due to the great differences between controls and inoculated pools.

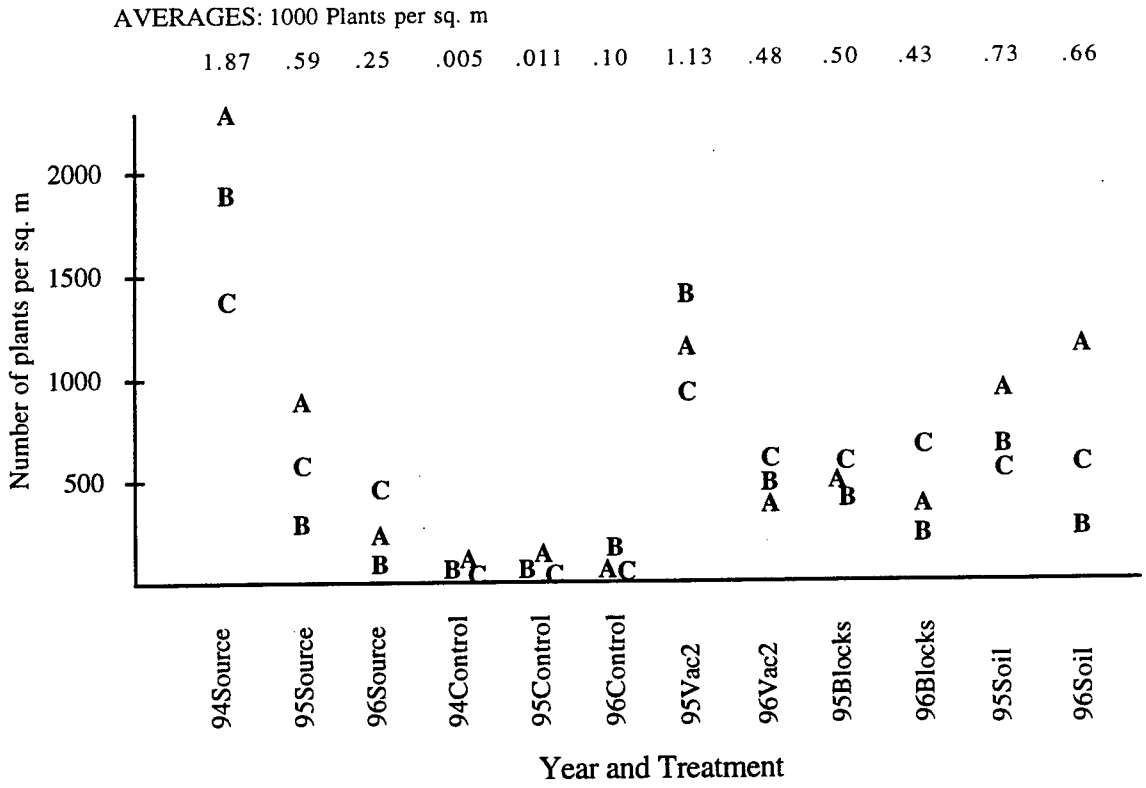

Figure 2.23. Comparison of treatments in density of native wetland plant species per m^2. Average values are shown at the top for comparison. Values for pools in each system are plotted with their respective letters: A, B, and C.

Average heights of plants increased in source pools from an average of 5.3 cm in 1993 (Fig. 2.20) to the 1994 value of 9.5 cm shown below (Fig. 2.24). In 1995, the value jumped to 13.6 cm and leveled off near that value in 1996. The increasing stature of plants is associated with the decline in density as native annuals decline. The inoculated pools lie just below or above the values for source pools in 1993. Values for stature of plants in controls gradually increased over three years.

In inoculated pools, height values have been similar in each year in each treatment and there is a statistically significant difference among them ($p \leq .0001$). The differences in this variable probably are due in part to differences in soils on the pool bottoms. As discussed in Chapter 1, the Vac treatments had seed and duff placed on a raw, clay, pool bottom. Soil as a treatment obviously included soil to a depth of approximately 10 cm. The added fertility in this treatment may support more robust plant growth. In Blocks, natural levels of soil mantle existed, and it is not clear why values were lower than for Soil. Notably, height has increased in controls over three years, albeit very slightly. There was also an effect of "system" in heights of plants in inoculated pools ($p = .0066$) due to higher values in B and lower ones in C.

When all created pools including controls were tested, significant effects of treatment ($p \leq .0001$) and system existed ($p = .0202$). The same factors had significant effects in the set of source and inoculated pools without controls: treatment had a p-value of $\leq .0001$ and system had a value of .0120. Inoculated pools had significantly higher values than controls and lower values than sources. The system effect is likely due to the generally low values in system C and possibly to high values in B.

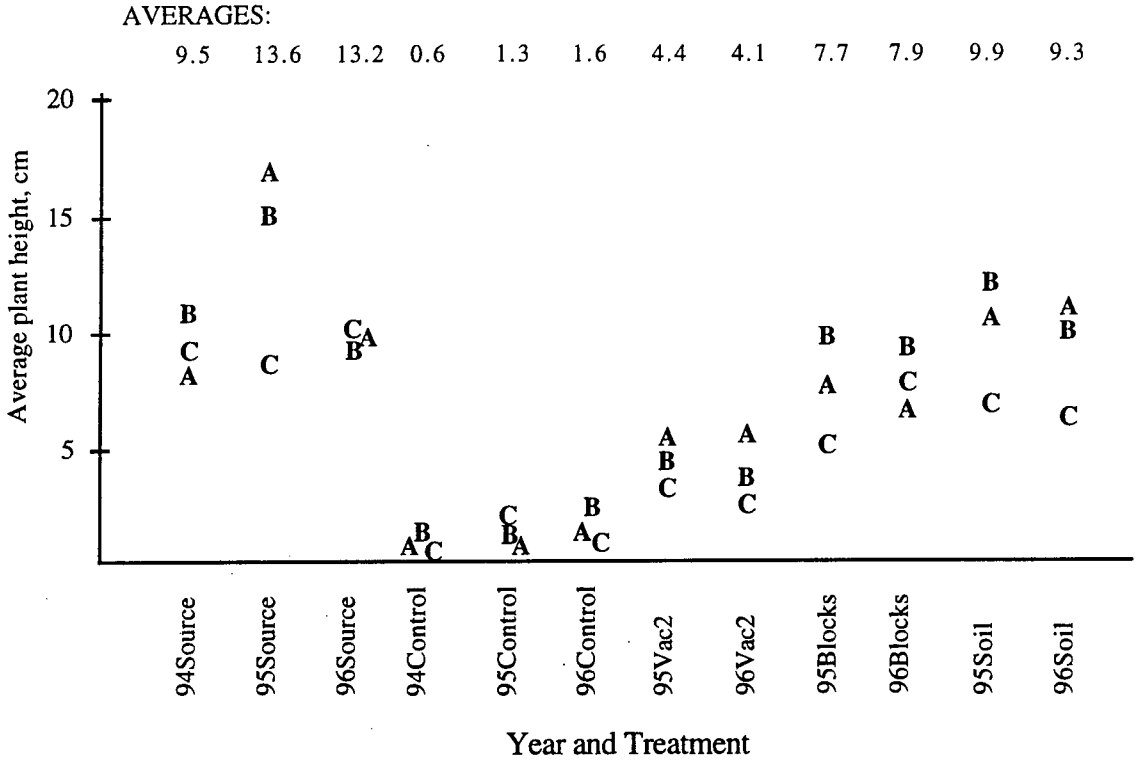

Figure 2.24. Comparison of treatments in height of native wetland plant species. Average values are shown at the top for comparison. Values for pools in each system are plotted with their respective letters: A, B, and C.

In the four variables analyzed for native wetland plants, relative density, species/sample, density, and height, Soil ranked highest, while Blocks and Vac2 each ranked second in two factors. These differences were statistically significant for relative cover and height. We view higher values for density and height as positive measures of success in the scale of this experiment, because they index generally successful reproduction and growth. Over longer periods of time, the same trends could be associated with decreasing diversity, as in source pools.

A major conclusion in addition to the superiority of using transplanted soil in inoculation is that inoculation of all types did produce success. The inoculated pools outperformed controls significantly in all ways, but the increase in values in controls over three years indicates that they are taking on characteristics of vernal pools.

Similarity of created pools to sources. An additional way of assessing the success of the created pools through two years is in how similar the composition of species is to that of the source pools from the source year of 1994. Percent similarity was used to gauge this factor. In contrast to the previous numerical analyses, where ten samples from each source and created pool were included, here we used the set of all samples from the source pools as the standard of comparison. All other samples were compared with these "total source in 1994" values. We included the same 10 samples from source pools each year (shown as "source" without the word "total") as a check to see how representative these samples were of the pools as a whole.

In Fig. 2.25, one can see that the total source samples are 100% similar to themselves, as must be true. The source samples taken to represent the pools (Source) are high in similarity in the year of inoculation (average 80%), verifying the validity of this use of subsamples for comparison with created pools.

One year after the source pool sampling, all values of similarity had dropped considerably, and there was not much difference between: (1) how the inoculated pools compared with the 1994 total source samples, and (2) how the source pool subsamples compared with the total source samples. Changes in the source pools themselves made them more dissimilar to their own 1994 values each year.

There was a slight decline in similarity values for all samples in 1996, and the inoculated pools were dropping in similarity to the source pools in the same manner as were comparisons of source pools to their own original values. Controls gradually increased in similarity.

Statistically, the set containing only inoculated pools showed no effect of treatment, but there was an effect of year ($p=.0194$) that is seen by the decline in values each year. When inoculated pools were combined with controls, there was a strong treatment effect ($p\leq.0001$) due to the much higher values in inoculated pools. When only source samples (not total source) were included with inoculated pools, there was no effect of treatment, indicating that inoculated pools were as similar to the original sources as were the samples used from 1994,

1995, and 1996 from the source pools. In this set there was again a strong effect of year ($p \leq .0001$) and an effect of system ($p = .0287$).

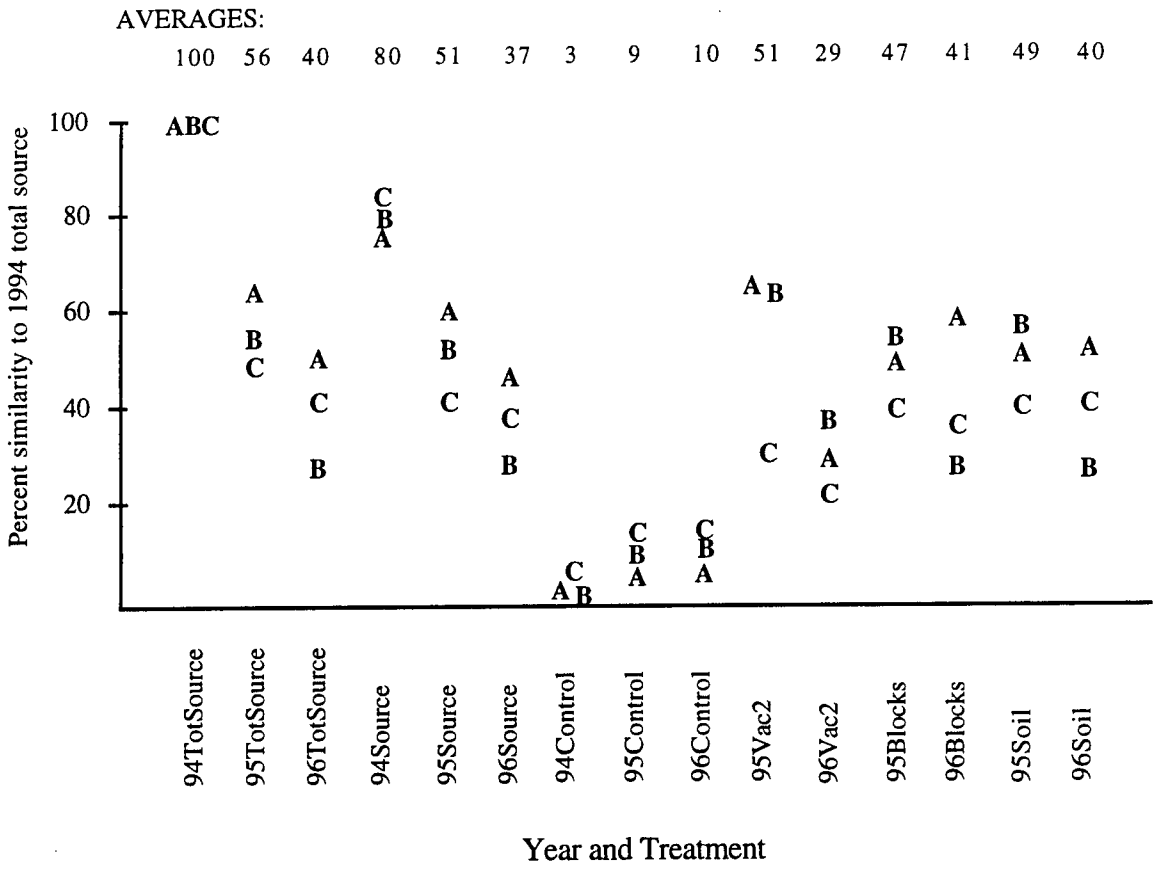

Figure 2.25. Percent similarity of controls, treatments, and source pool samples with the set of all samples ("TotSource") from the source pools in 1994. TotSource includes all samples from source pools each year. "Source" samples are the same ten randomly selected samples from each source pool used in other analyses in this chapter.

Perhaps better than any of the other analyses, this study of similarity emphasizes the value of continuing to monitor the changes in source pools and to judge created pools by noting how they express year-to-year trends. If the comparison here had only been made between created pools and the data from the source pools in the year of inoculation, the conclusion would have been that the inoculated pools are failing because they are getting further and further in species composition from source values.

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Chapter 3- Effect of Collection Techniques on Source Pools

INTRODUCTION TO MAJOR QUESTIONS

Creation of artificial vernal pools or restoration of natural ones will often involve removal of material from source pools. In many cases, these pools will be destroyed because they lie in the path of essential construction. In other instances, however, source pools may remain intact as part of a mitigation plan in which other pools are created nearby. The total effect of pool creation therefore needs to involve not only evaluation of the success of the created pools, discussed in Chapter 2 for plants and Chapter 4 for aquatic invertebrates, but the effect of removing materials from natural pools. This chapter describes our work to evaluate this effect.

To evaluate the effect on source pools of removing materials to transfer elsewhere, we established sets of plots adjacent to the baseline transects in source pools described in the previous chapter. We made our study plots of three sizes, the largest 1 m^2, to see if plot size would affect the response of the plant community to removal. We established four treatments for removal plots: (1) scraping and vacuuming in 1993 ("SV1"); (2) doing the same in 1994 ("SV2"); (3) in 1994, leaving unmodified the excavated plots from which loose soil was taken (Excavation, abbreviated "Exc"); and (4) in 1994, placing upland soil in the plots from which blocks were removed to restore the original level of the plots ("Fill"). (See Figs. 1.5-1.7.)

We undertook study of the SV method in two successive years only because seed was needed in these two years to answer questions about success of year 1 vs. year 2 created pools described in Chapter 2. We did not anticipate much difference between years in impact on the natural pools. To our surprise, however, the response in the two years was quite different, and results have major management implications.

In our excavation treatment, removal of soil created small depressions with different hydrological conditions from their surroundings, in addition to removing most of the seed bank and all of the dead vegetation. We anticipated that species would respond differently

on these plots than on those with unmodified topography. In application to actual mitigation projects elsewhere, deepening pools may often be required to remove accumulated sediments, restore topography altered by agriculture, or create hydrological conditions that favor a particular species targeted in mitigation.

The use of fill to restore natural topography in the fourth treatment was motivated by our curiosity about how well pools could perform two functions: (1) eliminating seed of upland plants that might have come in with the soil; and (2) colonizing the bare area with species from the pools themselves. In pool creation or restoration, times may arise when such fill is warranted, such as to modify the topography of a created pool to create shallower zones.

We sampled plants on each plot in the years following removal and compared measurements on the plant communities with unmodified plots (1993-96) in the adjacent baseline transects. We wanted to know:

1. if the size of removal plots would affect their response to the disturbance of removal;

2. what the impact of the four removal treatments on individual species would be, and what could be learned about the pools themselves from such an analysis; and

3. if the different methods used on the removal plots would have different effects in enhancing or retarding the native flora.

Our initial intent was simply to determine the manner in which the different removal methods affected the pools by tracking recovery of the plots from which soil and seed had been removed. As noted in Chapter 2, however, the pools were fenced for the duration of the work, resulting in cessation of the historical patterns of disturbance. The pools have lost species diversity and developed a covering of thatch under these conditions. Some exotic species have increased. Our removal plots have created local changes in the conditions of the pools, and therefore elucidate the process by which pools change. A number of our management recommendations follow from our analysis of the ecology of the pools based on this aspect of our study.

Because the pools themselves have been undergoing marked change, success of a given species under one of the removal methods did not involve simple recolonization of removal plots. Instead, it depended on how the species thrived under the one-time disturbance on the removal plots, declined under such disturbance, or maintained itself in the face of the experimental disturbance. Determining the impacts of one removal method

vs. another involved seeing if trends were positive for native plants collectively. Assessing impact also involved examining whether non-native species did better or worse on removal plots than on reference plots.

LIST OF MAJOR CONCLUSIONS

1. Plots from which materials had been removed recovered equally quickly on plots of all of the sizes we used. Up to square-meter size, plots will be repopulated by diverse assemblages of wetland plants within two years.

2. The removal plots mimicked patterns of disturbance similar to those in the recent history of the pools, and enhanced several native wetland species. Our samples included a total of 90 plant species in this portion of the study. Fifty-one of these were wetland plants, of which 35 were natives, including 28 annuals and 7 perennials. Among all plants, 38 had sufficient numbers to examine their distributions in pools, responses to removal methods in comparison with reference plots, and changes in abundance over the years. The species had unique responses, some increasing markedly while others disappeared during the course of the study. The conditions in which pools were protected from grazing, grading, and disking, led to very rapid change. Over the course of four years, ten small natives disappeared from the pools or were clearly on their way out. Four other small annuals clearly benefited from the disturbance caused by the removal methods. Six larger natives are likely to persist in the system on both removal and reference plots. Although some of these were reduced in abundance on removal plots, none were eliminated.

3. Three non-native wetland plants apparently were aided in establishment on plots by the scrape/vacuum method applied before the dry winter of 1994: *Briza minor*, *Lolium multiflorum*, and *Lythrum hyssopifolium.* Not only did they invade, but they persisted at higher levels than on plots cleared by the same method in the following year. Their invasion, combined with the temporary presence of seven other upland or weedy wetland non-natives, appears to have interfered with some natives for the following two years. This finding raised an important issue: the climatic conditions under which removal of materials from source pools takes place can lead to "initial conditions" on plots that affect community ecology into the future.

4. Four non-native wetland plants have increased throughout one or more of the pools, including on reference plots: *Cotula coronopifolia*, *Polygonum arenastrum*, *Polopogon monspeliensis*, and *Rumex crispus*. The expansion of these species, combined with the loss of natives, shows that management of the entire pool from which materials for inoculation are taken needs to be given as high a priority as the methods by which materials are removed.

5. All of the methods for removing inoculation materials, including addition of upland soil to plots, led to their having higher richness and abundance of small native wetland species than the unmodified reference plots. These plots represented small "islands" where the overall loss of diversity in the fenced pools was slowed down. Some larger native wetland species were reduced in abundance by the removal methods, but not harmed permanently. The three methods had different effects on the large and small native species, but overall, rated equally in having positive direct affects on native plants .

6. Plots on which upland soil had been placed showed significantly higher abundance and richness of non-native wetland plants after two years than plots of the other methods. The scrape/vacuum method showed the same negative effects to a lesser degree, and was also associated with invasion by non-natives in 1994 (conclusion 3). By contrast, simply removing soil and leaving the excavation unmodified did not lead to any of these adverse effects, and can be used safely for removing inoculum from source pools.

METHODS

Physical design. In each of the three source pools (TR5 for system A, TR17 for system B, and a set of 4 pools (TR1-4) for system C; Figs. 1.8 and 1.9) we set up eight zones for removal of materials. For clarity, the diagram of one such zone presented in Chapter 2 is repeated below as Fig. 3.1. Within each zone were located removal plots of three sizes (small-25 x 100 cm; medium-50 x 100 cm, and large-100 x 100 cm) for each of the four removal methods SV1, SV2, Exc, and Fill. The inoculation materials from each method within each of the three systems totaled 14 m^2 among all plots (8 of each size), and were transferred to a single created pool. We randomized which portion of the collection zone was used for each of the methods as well as the locations of the differently-sized plots within methods. All of the transplant work was done in late summer or early fall prior to the first rains.

All of the removal plots were marked with their designations on the corner adjacent to the sampling transect and closest to its starting point using a permanent plastic stake. PVC frames of the appropriate sizes were used to mark plot edges, both during later sampling and at the time inoculum for the created pools was removed. Methods of treating the plots were:

1. Method "SV1," 1993: All plant materials were scraped with a flat-bladed garden hoe into a large bag, then material from the surface was vacuumed into a second bag attached to a Echo model ES-1000 leaf blower (Fig. 1.5).

2. Method "SV2," 1994: The same as SV1 but a year later, in conjunction with the question about year-of-inoculation in created pools (Fig. 1.5).

3. Method "Exc," 1994: In this excavation method, a backhoe with it's small bucket was first used to loosen and then lightly crush the soil in the plots. This soil and dead plant parts associated with it were shoveled out of the marked plots by hand into a pickup truck and placed in the created pools. The excavations were left unfilled (Fig. 1.6).

4. Method "Fill," 1994: Using an electrical demolition hammer attached to a portable generator, the hardened soil within each plot was scored into 25 x 25 cm blocks. These were lifted by flat-bottomed shovels onto plywood pallets, which measured 30 cm by 1.2 m to accommodate 4 blocks and had 15 cm rails on the sides to keep blocks together. Pallets were transported by a pickup truck to the created pools. Following removal of the blocks, soil was added to the excavations to bring them back to the original level. This soil was taken from below the root zone of upland areas uphill and at least 25 m away from pools Fig. 1.7).

To summarize the design, we used:

Samples over 4 years 1993-96, with complete data sets on all methods in the last two (1995 and 1996).

3 pool systems: Widely spaced natural pools, with four nearly-adjoining small pools counting as one in system C. System A used Pool TR5; system B used Pool Tr17, and system C used Pools TR1-4. We have retained the word "system" for consistency with other parts of the study. The total system includes the source pool or pools plus five created pools not the topic of this chapter.

8 sampling zones along baseline transects in each system.

1 undisturbed reference sample and samples of three sizes for each of 4 methods in each zone.

Plant sampling methods. All data were taken by Susan Holve-Hensill in the same manner as described in Chapter 2. Briefly reiterated, a 20 x 50 cm frame of PVC

pipe was placed on the ground and used for visually estimating plant cover for each species, and density and height were also determined. Three such subsamples were taken in each removal plot, and the data were pooled into a single sample before being used for analysis. In the design, each of the four methods in each of the pool systems (A, B, or C) was represented by 24 samples each year, eight of each size. Because all of the plots of two methods were overlooked entirely in the 1994 sampling in zone 1 of system B (Pool TR17), we did not use data for any methods from this zone for any year, resulting in there being a total of 21 samples for each method in the 7 remaining sampling zones. For occasional other plots in 1995 or 1996 (9 of a total of 576) there were errors in data entry or a plot was missed. We used average numbers from the remaining plots of the same method in the same zone to represent the missing data in order to retain the symmetry of the design.

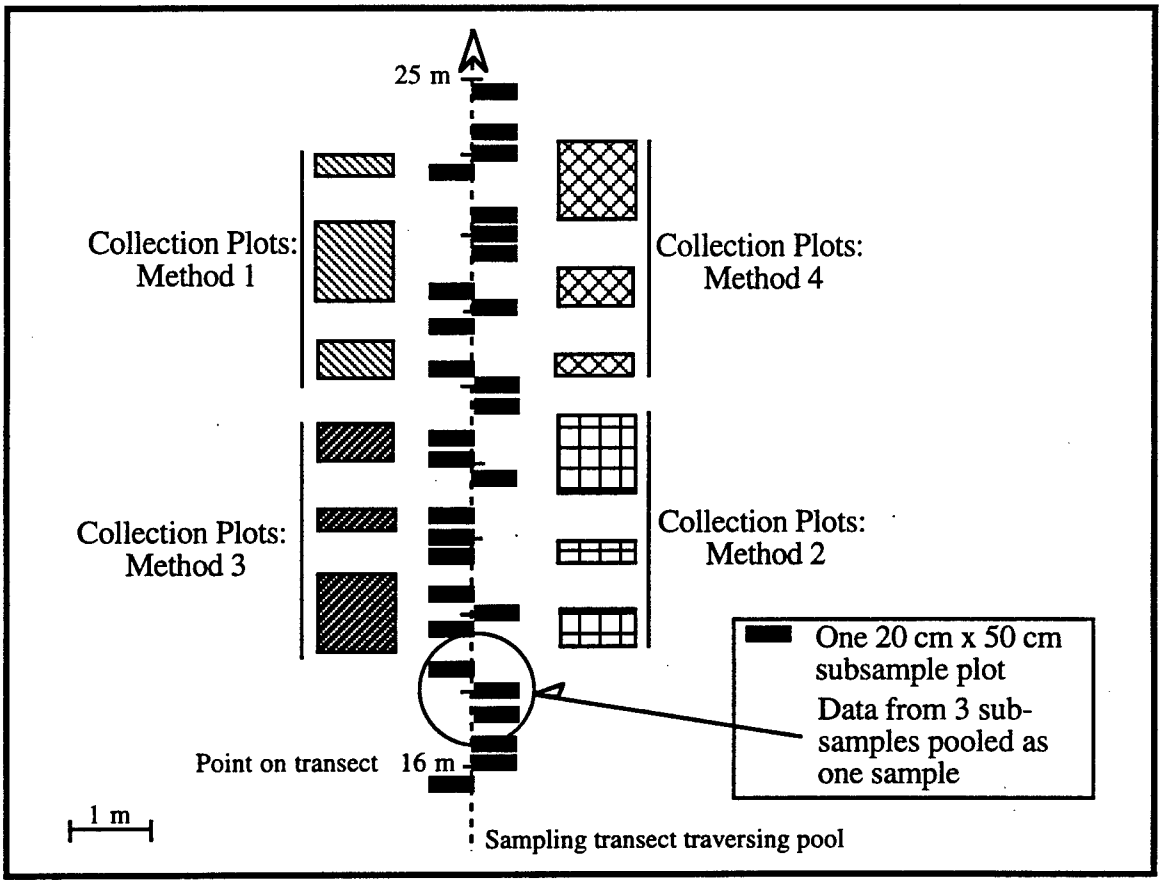

Figure 3.1. Diagram of a single sampling zone and collection plots within it on a segment of a baseline transect in a source pool, repeated from Chapter 2 for clarity. Each plot in each of the four methods was also sampled by three 20 x 50 cm subsamples each year. In the small plots, these overlapped.

To represent source pools in the analysis, we used the data from a single sample on the reference transect (pooled from three subsamples) within each zone. Each such sample was selected at random from among the 3-5 samples within each zone away from its ends

Analysis. All statistical evaluation was done using analysis of variance, according to the models given in Chapter 1. To analyze the effect of plot size, we used the set of data from years 1 (1995) and 2 (1996) of SV2, Exc, and Fill, since all removal of materials was done in 1994 under equivalent conditions. Along with the effect of "size" we evaluated the effects of "method," "year," and "system." Several different measures of plant cover were checked to see if there were an effect. For determining the differences among removal methods, we tested the set of data for 1995 and 1996 in the reference plots, SV2, Exc, and Fill. In a number of analyses, we also show data for 1993 and 1994 in the reference plots and for 1994-96 for SV1 because those values aid in interpretation of the results.

RESULTS

Effect of plot size. We anticipated that the plant community would recover from disturbance more rapidly on smaller plots because the centers of large plots are farther from the undisturbed sections of pools from which seeds and rhizomes might enter the plots. Using relative cover of plants and other pool items as the main variable, we examined a number of the major items and groups of items in the pools (plant species for the most part but including bare ground). There was not a significant effect of plot size in these measures. Other factors of "method", "year", and pool "system" did have significant effects, and will be discussed below. Examples of statistical results are given in Table 3.1, and three cover measurements are plotted in Fig. 3.2.

It is interesting that bare ground itself did not show a significant effect of plot size. In the field, larger plots appeared more "barren" than smaller ones, especially for Fill in 1995. When sampled with the small frame, however, the data did not show there to be a real difference.

Table 3.1. P-values for analysis of variance in four factors ("Method", "Size" of Plots, "Year," and "System") for four important cover values.

	p-Values			
Factor	All Wetland Plants	All Native Wetland Plants	All Native Annuals	Bare Ground
Method	≤.0001	≤.0001	≤.0001	≤.0001
Size	0.139	0.0776	0.0804	0.3971
Year	≤.0001	≤.0001	≤.0001	≤.0001
System	≤.0001	≤.0001	≤.0001	≤.0001

For measures of species richness, there was a significant effect of plot size on the number of species in an average sample. The number of wetland species, native wetland species, and native annual wetland species all had higher values overall in the large samples ($p \leq .0001$ for all three). Fig. 3.2 (top set of graphs) shows a representative pattern. The moderately higher values for some methods in one or both years probably resulted from the fact that the three subsamples were spread over a wider area in the larger plots, increasing the likelihood of samples including more species. In any case, even if the data do reflect a real pattern, they do not support the idea that smaller samples have less impact, because measurements of richness were higher in the larger samples.

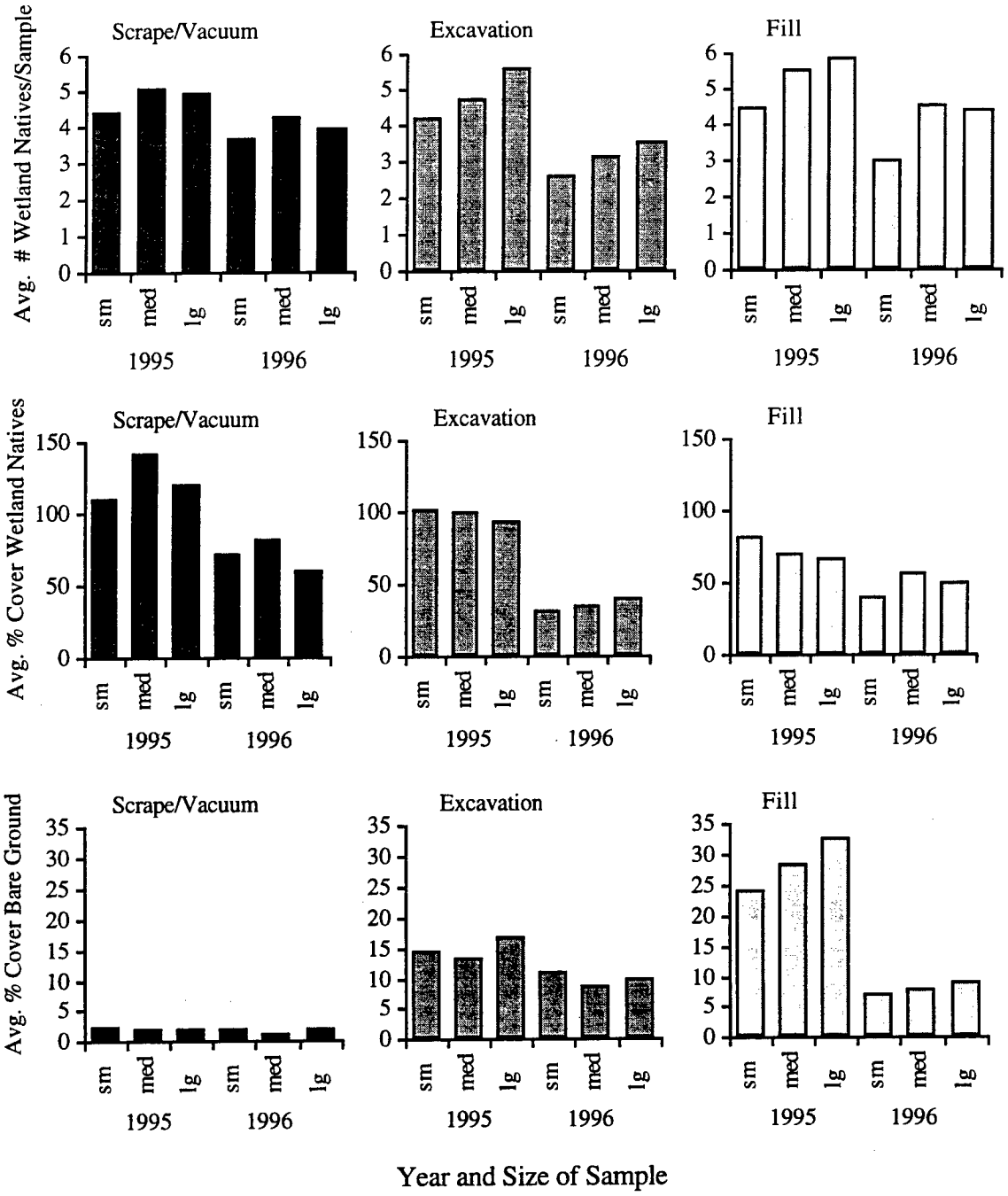

Figure 3.2. Average values for three variables among plots of different sizes in three methods over two years.

Statistical evaluation of the affect on individual plant species of removing materials from natural pools. Because plot size did not have a significant affect on success, this and the following analysis were based only on large plots. Samples were from source pools in 1993-96 (referred to as the reference samples, abbreviated "Ref"), 1994-96 on SV1 plots, and 1995 and 1996 on SV2, Exc, and Fill. For qualitative evaluation of trends, all samples were used; for statistics, only those from 1995 and 1996 for Ref, SV2, Exc, and Fill were utilized, because only these experienced the same physical conditions within the pools. (Note: In the statistical model, the reference plots are included under the factor "method." A significant p-value for "method" will thus be due to values in the reference plots and the removal plots.)

A first step in seeing the effect of the different factors on individual species was to determine the degree to which each species was present in each year, system, and method. We selected as a key variable the relative cover of the species as a percentage of the total of all items in the sample. The variable will show lower values if bare ground, thatch or other inanimate features occupy part of the space, but any possible differences in the judgments for estimating cover from day to day will be removed. Appendix C gives the average relative cover values for each species for each year, method, and pool system.

For many of the species, cover values were very small and appearance from one year to another did not show a pattern. For the remaining 38 species, as well as the factors "dead algal mats," "bare ground," and "thatch," however, trends could be noted. Graphs of these trends are also given in Appendix C. Because it had declined to near zero by 1994, outside of the samples used in statistics, *Vulpia bromoides* was not evaluated.

The results of the statistical analysis and a summary of the major trends are shown in Table 3.2. In this table, a p-value$\leq$.05 for "method" means that a notable difference among methods existed. Generally, such a pattern shows up in graphs from Appendix C. Where "system" had a significant p-value, the species was much less abundant or completely lacking in one or more of the three systems. A significant value for "year" indicated a pronounced pattern of increase or decline from 1995 to 1996. Both review of the table and of appended materials show that species vary notably in their response to the experiment.

Table 3.2. Summary of the response of 38 more abundant plant species and three physical factors to the experiment. The table shows p-values from analysis of variance for "method," "year," and "system;" plot types favoring or disfavoring species or physical factor; and short descriptions of the response. p≤0.0001 is abbreviated "0.0001."

Species or Item	P-Values: Method	System	Year	Favored by:	Disfavored by:
Dead algal mats	0.0001	0.0001	0.0001	Exc	
Increased notably in 1996; highest on excavated plots.					
Bare ground	0.0001	0.7962	0.0001	Fill Exc	Ref SV1 SV2
Declined markedly in year 2 after initially high values on excavated plots and those filled with upland soil. Was high on reference plots of 1993 before decline to near zero one year after removal of historic disturbance patterns.					
Thatch	0.0056	0.0012	0.0008	Ref SV1 SV2	Exc
Strongly increased in year 2, with highest values on reference plots.					
Achyrachaena mollis	0.1707	0.1980	0.1797	SV1 SV2	Exc
This small native annual of marginally wet areas increased on the SV plots. It was not found on reference plots, and only marginally on Fill. Seed on pool bottoms may have been released from dormancy by the scraping.					
Briza minor	0.0636	0.2000	0.1178	SV1 Fill	Exc
This small non-native wetland grass reached moderate levels on the SV1, SV2, and Fill plots in the year after removal of materials and increased on them. Did not do well on Exc plots, possibly because of deeper water.					
Bromus hordeaceus	0.0803	0.0989	0.8049	SV1	SV2 Exc
This mid-sized annual upland grass had small cover values on SV1, which it may have been able to invade in the dry year of 1994.					
Centaurea solstitialis	0.0842	0.4774	0.2136	SV1 Fill	SV2 Exc
An upland weed that showed up in 1994 SV1 and then declined. May have had seed on soil of Fill where it had a small presence in 1995; gone or nearly so by 1996 on all plots.					
Cotula coronopifolia	0.0125	0.0001	0.0024		
A low-growing non-native wetland perennial. Generally increasing on all plots. Response varies in the three pool systems.					

Table 3.2. continued

Species or Item	P-Values: Method	System	Year	Favored by:	Disfavored by:
Crassula aquatica	.0078	.0743	.5084	Exc	Ref SV1
	A very small annual wetland native that disappeared from reference plots the year after they were fenced. Retained on the excavations and to a lesser extent on Fill. Appears to require very open habitat.				
Deschampsia danthonioides	0.3088	0.0001	0.6539		
	A small native wetland grass, that increased notably in year 2 on reference plots and then decreased in system B but increased or remained steady in C. (Not present in A.)				
Downingia concolor	0.0001	0.0001	0.0161	SV2 Fill Exc	SV1
	Opening of the habitat by the removal methods generally helped this small native wetland annual. On SV1, this was not the case. Perhaps the dry-year invasion of competing species with less strong wetland affinities kept it from increasing as it did on the other disturbed plots one year later.				
Eleocharis macrostachya	0.5404	0.0001	0.1176		
	This mid-sized, wiry, wetland perennial occurs only in the more mesic source pool (TR5) of system A. Has increased over two years on all plots. Was not completely removed from excavated plots because rhizomes had to be cut to lift blocks. Was able to reestablish itself on filled plots in the first year.				
Epilobium brachycarpum	.4369	.3950	.3411	SV1 Fill	Ref SV2 Exc
	A tall, late-flowering, non-native, upland annual. Much more on SV1 than SV2, possibly because it was able to invade in the dry year of 1994. May have had seed on soil of Fill, where it appeared in 1995; gone by 1996.				
Epilobium densiflorum	.4837	.2039	.2125	SV1 SV2 Fill	Ref
	This native wetland annual showed up in very small numbers on all disturbed plots in year 1, and then disappeared.				
Eremocarpus setigerus	0.3607	0.0001	0.7813		
	This native, summer-growing, upland plant often invades pools. Generally lacking on reference and removal plots of system B (pool TR17) even though this pool has a history of strong disturbance.				
Erodium botrys	0.2220	0.0115	0.1979		
	This small upland annual can invade pools in dry years. It did so on reference plots and SV1 in 1994. Disappeared or nearly so in 1995 and 1996.				

Table 3.2. continued

Species or Item	P-Values: Method	System	Year	Favored by:	Disfavored by:
Eryngium aristulatum var. *aristulatum*	0.0001	0.0001	0.9166	Ref SV1 SV2	Exc Fill
	This native wetland perennial occurs primarily in system A, but may be invading B. Cover reduced notably by the excavation and fill methods.				
Hemizonia parryi	0.1051	0.0001	0.0091	Ref SV1 SV2 Fill	Exc
	Native, late-season wetland annual of system C that appeared first in 1995 on reference plots. Declined in 1996.				
Hemizonia pungens	0.3038	0.0001	0.2007		
	Native, late-season wetland annual of system B that had moderately high cover in 1994 and low or no cover on all plots in 1995 and 1996.				
Hordeum marinum ssp. *gussoneanum*	0.0233	0.0045	0.0705		Exc
	Non-native, annual, facultative grass that often takes over shallow zones of pools. Variable, moderately high cover values 1993-95, but decline in 1996.				
Hypochaeris glabra	0.0443	0.0549	0.7694	SV1 Fill	Ref SV2 Exc
	Non-native upland annual of system C that was present in low values on SV1 and Fill.				
Juncus bufonius	0.0001	0.0047	0.0005	SV1 Fill	Ref SV2 Exc
	Small native wetland annual common in low flat areas. Declined on reference plots, and all plots from 1995 to 1996. Did best on SV1 and Fill.				
Lasthenia glaberrima	0.0011	0.0001	0.0001		Fill
	Moderately small, native, wetland annual that maintained a presence on all plots, although declining in 1996. Uncommon or absent on filled plots.				
Lilaea scilloides	0.4613	0.2076	0.0200		
	Small, native, wetland annual common in many disturbed areas. Absent from removal plots in 1995, but appeared in 1996.				
Lolium multiflorum	0.0006	0.0234	0.5010	SV1 Fill	Exc
	Strong, non-native, annual, facultative grass that often overtakes pools. Maintained a presence on reference plots, and increased notably on SV1 over three years. Initially invaded fill or came in with soil, and maintained itself into 1996. Excluded on excavated plots, probably by deeper water.				

Table 3.2. continued

Species or Item	P-Values: Method	System	Year	Favored by:	Disfavored by:
Lythrum hyssopi-folium	0.0103	0.0844	0.1566	All removal plots	
	Non-native wetland annual that declined on reference plots, but maintained higher levels on removal plots, on which cover went up or down from 1995 to 1996.				
Navarretia intertexta ssp. *intertexta*	0.8628	0.0134	0.0556		SV1
	Small, native, wetland annual that was first noted on reference plots in 1994, then declined to zero in 1996. Never invaded SV1, possibly because of competition with facultative or upland plants in 1994. Was present on other removal plots in 1995 but not 1996.				
Picris echioides	0.0055	0.0020	0.2566	Ref SV1	SV2 Exc Fill
	Vigorous, weedy, facultative, non-native annual that invaded SV1 in 1994 and persisted through 1996. Did not similarly invade other removal plots in 1995.				
Pilularia americana	0.0002	0.0498	0.0408	Fill	Ref
	Tiny, grass-like, native, wetland fern that disappeared in 1994, the year after fencing of pools. Strongly invaded filled plots in 1995 suggesting that spores may have present in the introduced soil. Reached approximately equivalent levels on all disturbed plots by 1996, but did not develop more than minimal cover values on reference plots.				
Plagiobothrys greenei	0.3898	0.0853	0.0663		
	Moderately small, native, wetland annual that increased on reference plots and SV1 from 1993 to 1994, then declined. Present on plots of all removal methods in 1995 but not 1996.				
Plagiobothrys stipitatus var. *micranthus*	0.1794	0.0001	0.0001		
	Moderately small, native, wetland annual that declined slowly on all plot types but remained present in 1996.				
Plagiobothrys trachy-carpus	0.0001	0.0001	0.0001		
	Moderately small, native, wetland annual that declined on reference plots after a rise from 1993 to 1994. Present but with declining values on all removal plots, but did less well on Fill.				
Pleuropogon californ-icus	0.0009	0.0001	0.0530	Ref	
	Tall, native, annual wetland grass that has increased on reference plots. On removal plots, has increased in system B and decreased in C. (Not present in A.) Did less well on excavated or filled plots, but still present.				

Table 3.2. continued

Species or Item	P-Values: Method	System	Year	Favored by:	Disfavored by:
Polygonum arenastrum	0.6726	0.0001	0.0001		
	This straggly, prostrate non-native wetland annual has increased on all plot types after first appearing in 1995.				
Polypogon monspeliensis	0.4951	0.0037	0.0229		
	This non-native wetland grass increased notably on reference plots from 1993 to 1995 and remained at high levels in 1996. Trends and cover values are generally reflected on all types of removal plots.				
Psilocarphus brevissimus var. *multiflorus*	0.2752	0.0150	0.2698		SV2
	This very small, native, wetland annual may have increased minimally on reference plots, but was never common. Appears to have done better on the open, Exc and Fill plots, but the difference is not significant.				
Rumex crispus	0.0085	0.0001	0.0001		
	This strong, tall, non-native wetland perennial has increased on plots of all types.				
Spergula arvensis ssp. *arvensis*	0.2921	0.0223	0.1680	SV1 Fill	SV2
	This small, non-native, upland plant is often found in somewhat wet areas. It had moderately high cover areas on SV1 in 1994 and 1995, but was gone in 1996. It was probably aided by the dry year of 1994. The plant was present on the excavated and filled plots in 1995, but only on fill in 1996.				
Veronica peregrina ssp. *xalapensis*	0.8016	0.0636	0.0092		
	This small, native, wetland annual maintained itself on reference plots at low levels through 1995, but was not found in 1996. It had notably higher values on disturbed plots in the first year, but was gone or nearly so in 1996.				
Vulpia bromoides	na	na	na		
	This non-native, annual wetland grass declined notably on reference sites the year after they were fenced.				
Xanthium strumarium	0.3698	0.0001	0.0743		
	This tall, native, wetland annual invades disturbed areas, including riparian zones and wetlands other than vernal pools. It was present at low levels only in the more mesic source pool of system A.				

Not surprisingly given the great change in the pools as plants responded to a change in the disturbance regime, there were great effects of "year" in the statistical evaluations. Thirteen of the 37 species in Table 3.2 that could be evaluated (excludes *Vulpia bromoides*) showed such an effect.

Equally notable is that 25 of 37 evaluated plant species showed significant effects of "system." Many were present in only one or two of the three pool systems. The appendix graph for *P. californicus* is duplicated as Fig. 3.3 as and example of this pattern. The plant was present in only two systems, and had a p-value of ≤.0001 for this factor. In several cases, such as *Downingia concolor*, *Deschampsia danthonioides*, and *P. californicus*, the species declined from 1995 to 1996 in one pool system and increased in another, seen in Fig. 3.3 for *P. californicus*. Such countertrends obscured the statistical test for the effect of "year" for this species.

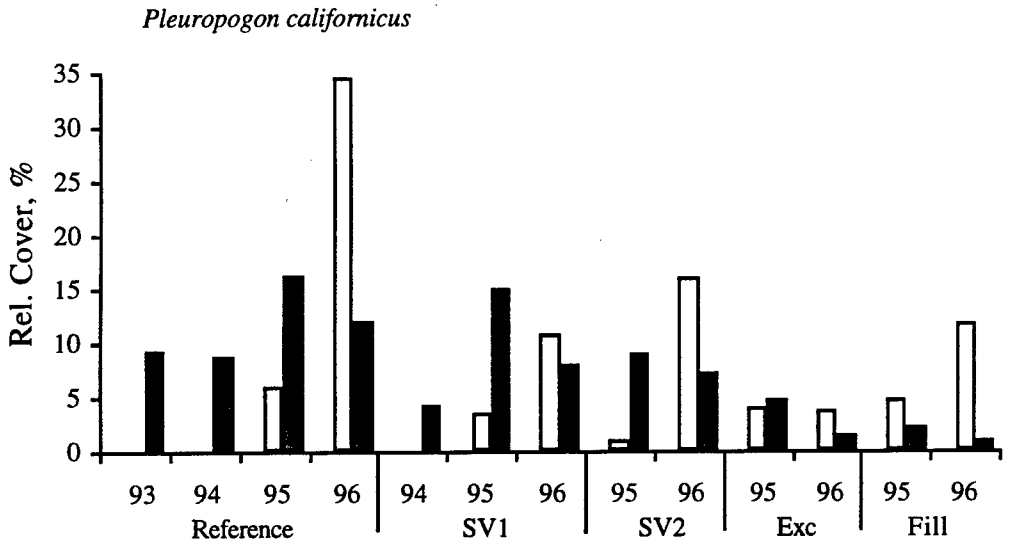

Figure 3.3. Relative cover for *Pleuropogon californicus*. On the x-axis, years and sample types are shown. White bars represent pool system B, gray, system C. The species was not present in system A.

Among species evaluated, 15 of 37 showed significant effects of "method". Patterns in the graphs of relative cover show why this was so, which in turn can help determine whether the removal of inoculum benefited or harmed the species in question. Removal of materials from pools by one or more methods clearly benefited four small native species: *Crassula aquatica*, *Downingia concolor*, *Juncus bufonius*, and *Pilularia americana*. Removal plots had a small negative effect on the non-native, perennial *Rumex crispus*. On the other hand, one or more removal methods adversely affected four natives *Eryngium aristulatum* var. *aristulatum*, *Lasthenia glaberrima*, *Plagiobothrys trachycarpus*, and *Pleuropogon californicus*. For these, however, there were always other removal methods with little or no effect, and generally it was Fill among methods that had values below those for the reference sites.

Among non-natives, one or more removal methods enhanced *Cotula coronopifolia*, *Hypochaeris glabra*, *Lolium multiflorum*, and *Lythrum hyssopifolium*. Cover values for *H. glabra* are low, and the trend is one of decline for this upland plant, hence it is of little real concern. The other three represent major invasive species, and these results are of concern. In two other non-native wetland species, *Hordeum marinum* ssp. *gussoneanum* and *Picris echioides*, values were higher for some removal method than for the reference, but lower in other removal methods; some aided and some retarded the species. Both species have declined in general and are apparently not of concern.

In this section, we found some native and some non-native species have benefited from the removal experiment, and some have had their abundance reduced. Because the species have different properties, and cannot be placed on the same scale of value, a simple numerical tally of these consequences cannot fully answer the question of benefit vs. cost of a given method. In the section immediately following, we describe how patterns of response shared by species help answer this question. The final section of the chapter compares methods by use of aggregate measures of success, such as cover or species richness of selected sets of native and non-native plants.

Community dynamics of the vernal pools as elucidated by the study. Evaluation of the graphs in Appendix C for trends among the more abundant species, including some for which the statistical effect of "method" was not significant, shows that there are several major changes in the community ecology of the pools that provide a more complete view of the desirability of removing of materials from pools than looking individually at the species. Graphs in this section duplicate those in the appendix, and are repeated to illustrate examples.

We identified six major trends in the species:

1. Nine native wetland species disappeared very early from the pools, almost certainly due to an inability to compete without removal of their competitors. One other, *Plagiobothrys trachycarpus*, showed a pattern of slower decline but is probably disappearing. Removal of materials from collection plots enhanced some of these species, or at least postponed their demise. The nine species are:

   Crassula aquatica
   Hemizonia parryi
   Juncus bufonius
   Lasthenia glaberrima
   Navarretia intertexta ssp. *intertexta*
   Pilularia americana
   Plagiobothrys greenei
   Plagiobothrys stipitatus var. *micranthus*
   Veronica peregrina ssp. *xalapensis*

The graph for *C. aquatica* shows a decline to near zero on reference plots, but existence into 1996 on areas of removal (Fig. 3.4). *V. peregrina* ssp. *xalapensis* benefited from the removal activities, but was essentially gone by 1996 (Fig. 3.5), and *Plagiobothrys greenei* was completely gone by 1996.

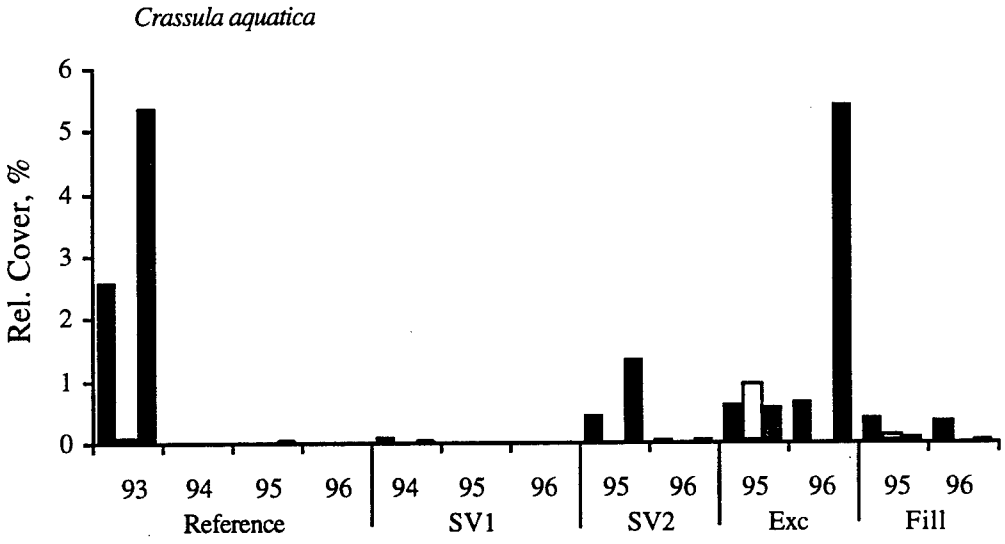

Figure 3.4. Relative cover for *Crassula aquatica*. On the x-axis, years and sample types are shown. Black bars represent pool system A, white bars represent B, and gray, system C.

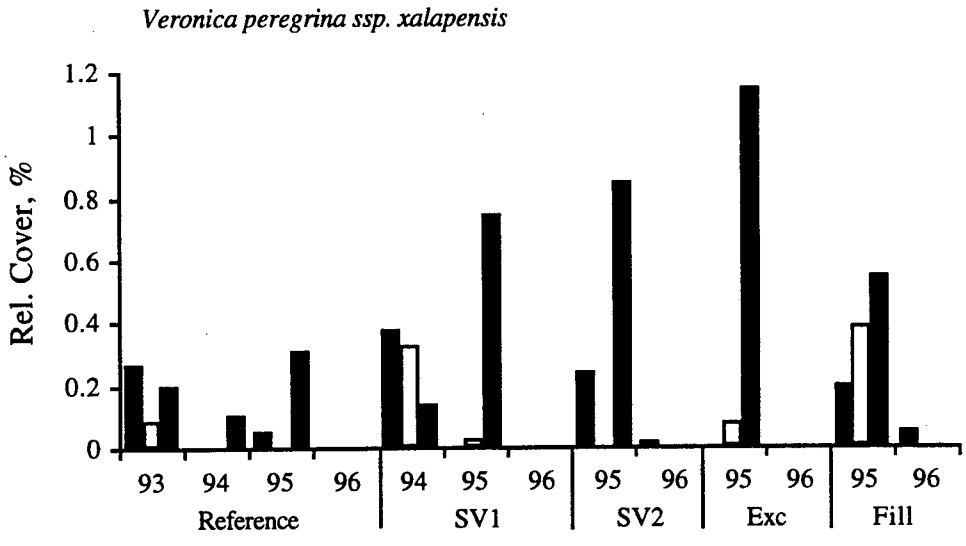

Figure 3.5. Relative cover for *Veronica peregrina* ssp. *xalapensis*. On the x-axis, years and sample types are shown. Black bars represent pool system A, white bars represent B, and gray, system C.

2. Three native wetland annuals, *Achyrachaena mollis*, *Lilaea scilloides*, and *Psilocarphus brevissimus* var. *multiflorus*, increased on one or more removal plots, and had zero or very low cover on reference plots. Fig. 3.6 shows the last of these.

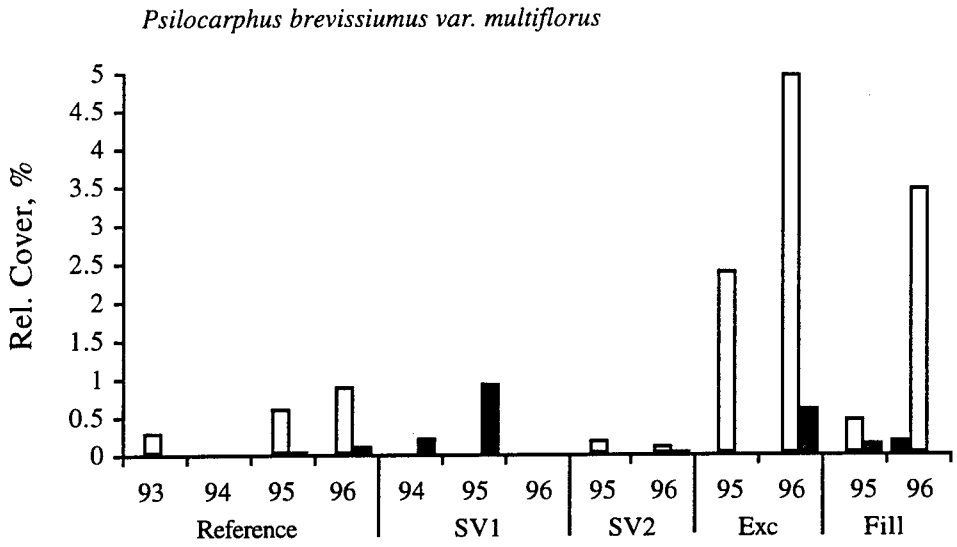

Figure 3.6. Relative cover for *Psilocarphus brevissimus* var. *multiflorus*. On the x-axis, years and sample types are shown. Black bars represent pool system A, white bars represent B, and gray, system C.

3. Seven native species showed patterns of increase or maintenance of populations on reference plots and most removal plots. These are likely to persist in pools with or without the disturbance of the removal methods. *Eryngium aristulatum* var. *aristulatum* (shown below in Fig. 3.7) did poorly on Exc and Fill, *Downingia concolor* (Fig. 3.8), did poorly on SV1 and may be declining on Ref, and *Hemizonia pungens* flourished in 1994 on Ref and SV1, but the other four species showed little difference among methods. *Pleuropogon californicus* is shown above in Fig. 3.3. These species are:

Deschampsia danthonioides
Downingia concolor
Eleocharis macrostachya
Eryngium aristulatum var. *aristulatum*
Hemizonia pungens
Pleuropogon californicus
Xanthium strumarium

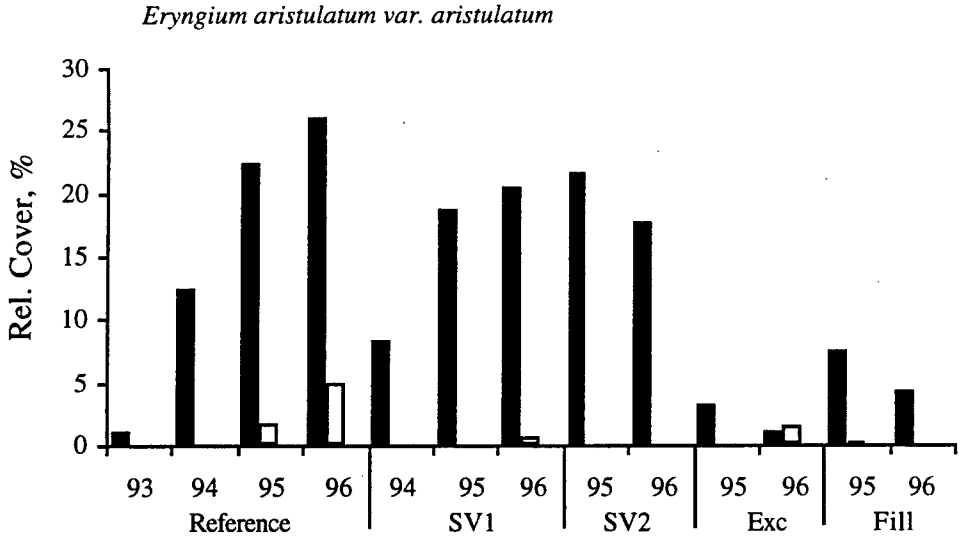

Figure 3.7. Relative cover for *Eryngium aristulatum* var. *aristulatum*. On the x-axis, years and sample types are shown. Black bars represent pool system A, white bars represent B, and gray, system C.

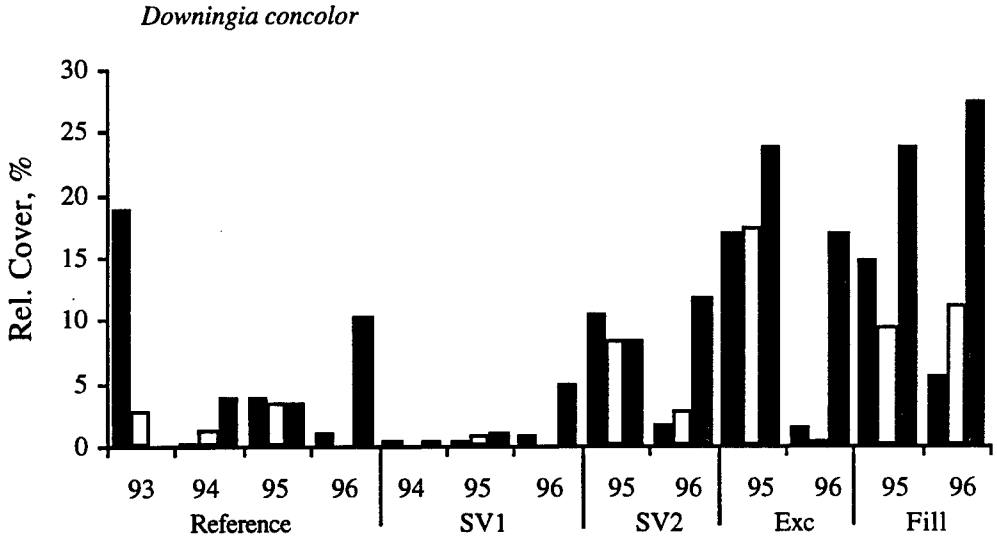

Figure 3.8. Relative cover for *Downingia concolor*. On the x-axis, years and sample types are shown. Black bars represent pool system A, white bars represent B, and gray, system C.

D. concolor was particularly strong on Fill but it also benefited from SV2 and Exc. It continued to have a strong presence on reference plots of system C in 1996, but was not in samples from system B and had low values in A.

4. Four non-native species had notable cover values on removal plots only in the dry year of 1994 on the disturbed SV1, during which year they also increased on reference plots. All disappeared or declined sharply in following years on both reference plots and SV1, indicating that they lack to capacity to remain in pools. These are listed below, with one illustrated in Fig. 3.9.

Centaurea solstitialis
Erodium botrys
Picris echiodes
Spergula arvensis ssp. *arvensis*

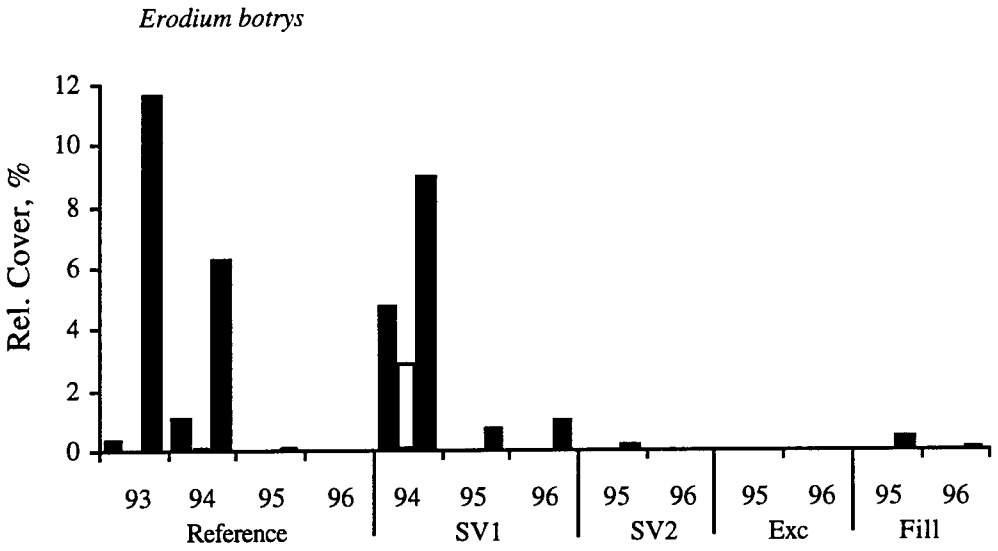

Figure 3.9. Relative cover for *Erodium botrys*. On the x-axis, years and sample types are shown. Black bars represent pool system A, white bars represent B, and gray, system C.

Among these four species, only *P. echioides* is classified as a wetland plant (FAC* in Reed 1988). *E. botrys* and *S. a.* ssp. *arvensis* appear occasionally in wetlands, even though this affinity is not recognized (neither is listed in Reed, therefore they are considered to be upland plants.) *C. solstiatialis* appears to be more strictly an upland species, and would not be expected to persist in pools, as it didn't.

5. Six non-native species, like those of group (2) above, had notably higher cover values on removal plots only in the dry year of 1994 on the disturbed SV1. In contrast with the previous species, however, they were absent or of much lower cover on the reference plots. Three of these are wetland species capable of maintaining themselves or expanding in the pools (*Briza minor*, *Lolium multiflorum*, and *Lythrum hyssopifolium*). (*Hordeum marinum* ssp. *gussoneanum*, not on this list, was strong on both Ref and SV1, but has since declined.) Responses of these three wetland species to the experiment are shown in Figs. 3.10, 3.11, and 3.12.

Bromus hordeaceus
Briza minor
Epilobium brachycarpum
Hypochaeris glabra
Lolium multiflorum
Lythrum hyssopifolium

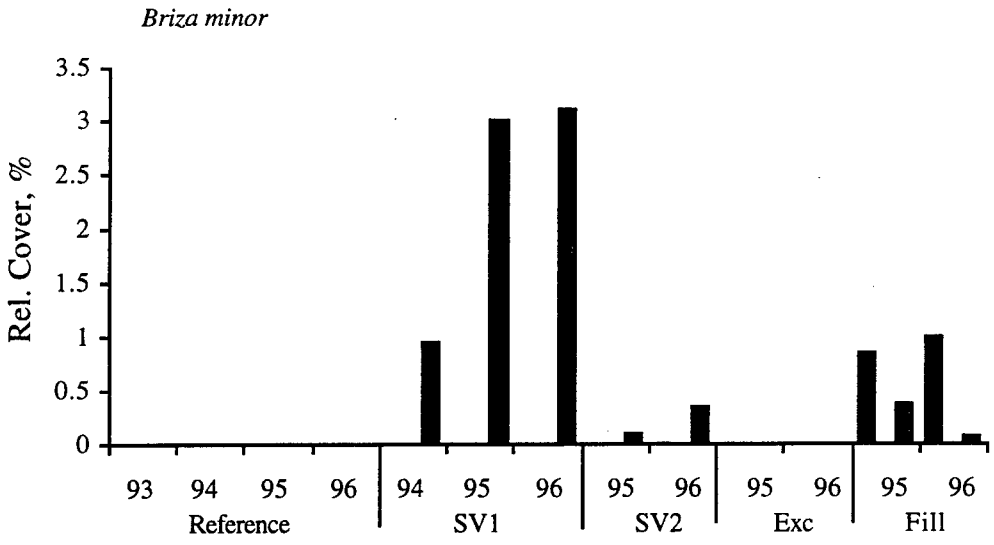

Figure 3.10. Relative cover for *Briza minor*. On the x-axis, years and sample types are shown. Black bars represent pool system A, and gray system C.

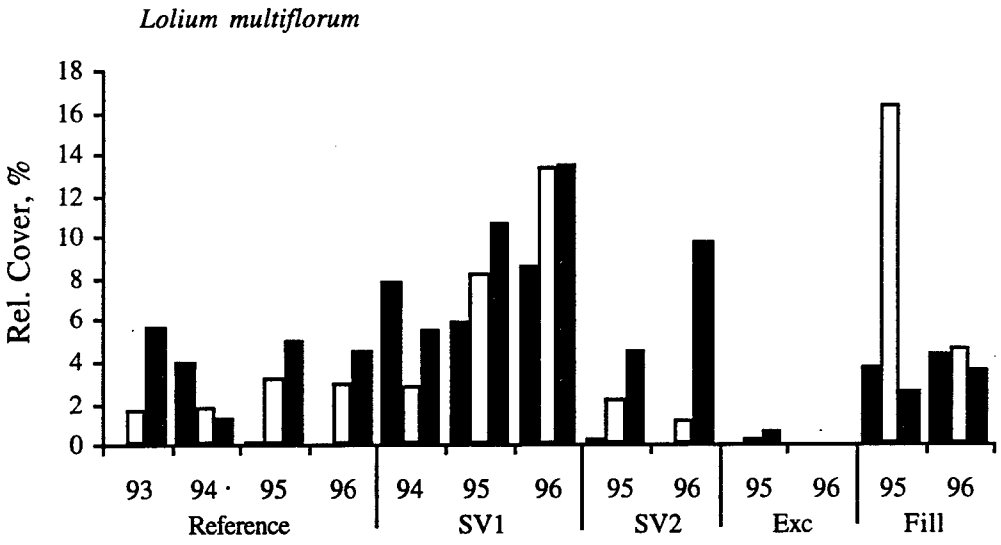

Figure 3.11. Relative cover for *Lolium multiflorum*. On the x-axis, years and sample types are shown. Black bars represent pool system A, white bars represent B, and gray, system C.

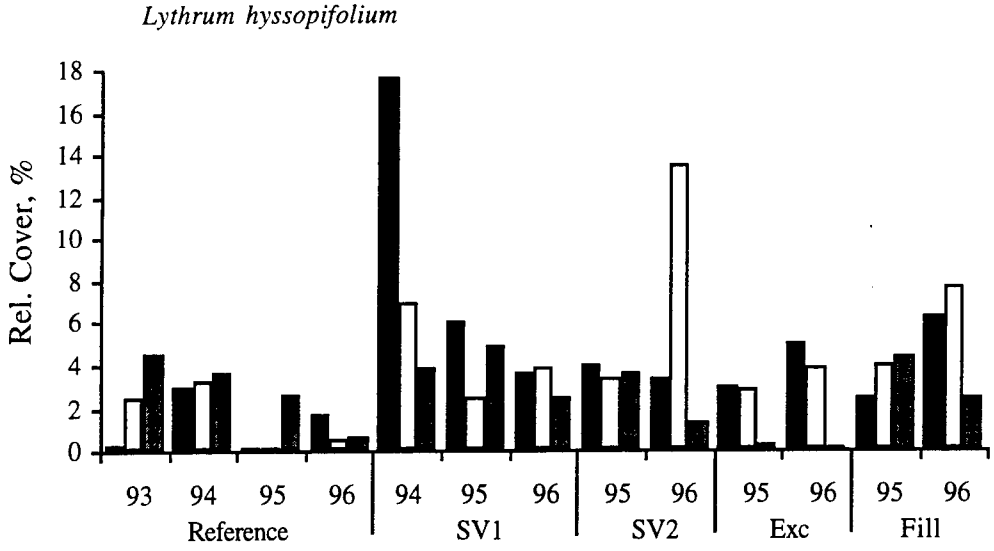

Figure 3.12. Relative cover for *Lythrum hyssopifolium*. On the x-axis, years and sample types are shown. Black bars represent pool system A, white bars represent B, and gray, system C.

For both *B. minor* and *L. multiflorum*, the foothold they gained on the SV1 plots led to continued increase in future years, and a fundamentally different pattern of plant species abundances than that found in exactly the same treatment a year later, SV2. This fundamental difference, in the form of higher values on SV1 and lower ones on SV2 for wetland plants (excluding the those from (2) above in which the only presence was on SV1 in 1994) was also seen in the non-natives *Cotula coronopifolia*, *Hordeum marinum* ssp. *gussoneanum*, and the native *J. bufonius*.

The initial conditions of plots, in this case being relatively free of competition during a dry year, changed events for several years. Such a finding may be important for future restoration. If weather prediction reaches the state where below average and above average rainfall can be predicted from summer to the following winter, removal of seed and/or soil could be limited to wet years. Alternatively, in the year following removal, pools could be maintained artificially by watering into mid-April to retain the hydration they would experience in a wet year.

In 1994, values for two native wetland species, *Downingia concolor* and *Crassula aquatica*, were low on SV1 plots. In the following year their cover values were much higher on SV2, which had not been invaded in 1994 by significant numbers of these non-natives. Competition from the non-native species may have depressed these species in comparison with their responses on SV2 one and two

years following seed removal. Several other native wetland plants, such as *Lasthenia glaberrima* and three species of *Plagiobothrys*, did not show this pattern.

6. Four non-native wetland species showed a pattern of progressive increase in the pools without initially high values in 1994. These species also showed patterns of increase on the reference sites. The pattern for *Cotula coronopifolia* is shown in Fig. 3.13. The four species are:

Cotula coronopifolia	*Polypogon monspeliensis*
Polygonum arenastrum	*Rumex crispus*

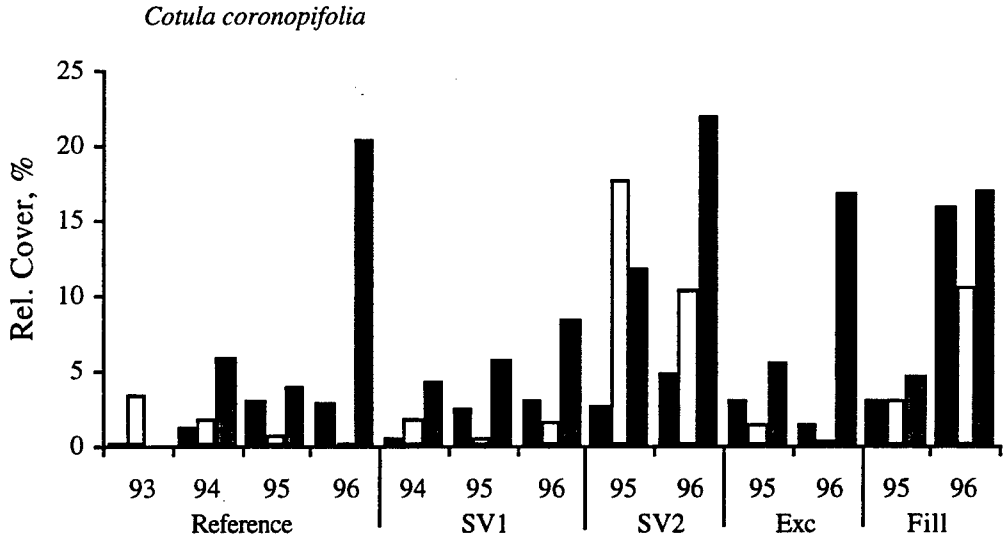

Figure 3.13. Relative cover for *Cotula coronopifolia*. On the x-axis, years and sample types are shown. Black bars represent pool system A, white bars represent B, and gray, system C.

This analysis of the dynamic response of species over the term of this study shows that fully 10 of the analyzed 20 native wetland species have markedly declined or disappeared under protection from disturbance. Some of these benefited from one or more removal method. Three native species appear to have been retained on plots because of the disturbance of removal. Seven natives are likely to persist in the pools irrespective of the management regime. Table 3.3 provides a summary of these groups of plants. One native not classified into any of the groups above is *Epilobium densiflorum*, a late-flowering wetland annual that appeared on removal plots of system C in 1995 but was not there in 1996. Another is *Eremocarpus setigerus*, a summer annual that invades dry pools.

Among non-natives, four invaded in 1994 and then disappeared, and four that also invaded in that year are unlikely to hold on in the pools at any significant level (Table 3.3). Three wetland non-natives appear to have invaded much more strongly in 1994, and used that success to gain a permanent foothold on those plots. Four non-natives have been gradually increasing in the pools unrelated to the experiment. One non-native was not placed in any group, *Vulpia bromoides*, is a wetland grass that did not survive past 1993 in the reference sites.

Table 3.3. Listing of the more important species in the study by groups.

Set 1: Natives gone or rapidly declining:

Crassula aquatica	*Pilularia americana*
Hemizonia parryi	*Plagiobothrys greenei*
Juncus bufonius	*Plagiobothrys stipitatus* var. *micranthus*
Lasthenia glaberrima	*Plagiobothrys trachycarpus*
Navarretia intertexta ssp. *intertexta*	*Veronica peregrina* ssp. *xalapensis*

Set 2: Natives apparently benefiting on removal plots:

Achyrachaena mollis
Lilaea scilloides
Psilocarphus brevissimus var. *multiflorus*

Set 3: Natives persisting or likely to persist with or without disturbance:

Deschampsia danthonioides	*Hemizonia pungens*
Downingia concolor	*Pleuropogon californicus*
Eleocharis macrostachya	*Xanthium strumarium*
Eryngium aristulatum var. *aristulatum*	

Set 4: Non-natives with strong presence on SV1 in 1994; unlikely to persist:

Bromus hordeaceus	*Hordeum marinum* ssp. *gussoneanum*
Centaurea solstitialis	*Hypochaeris glabra*
Epilobium brachycarpum	*Picris echiodes*
Erodium botrys	*Spergula arvensis* ssp. *arvensis*

Set 5: Non-native wetland plants with higher values on SV1 than SV2; likely to persist:

Briza minor
Lolium multiflorum
Lythrum hyssopifolium

Set 6: Non-natives increasing with or without disturbance:

Cotula coronopifolia	*Polypogon monspeliensis*
Polygonum arenastrum	*Rumex crispus*

The important concerns stemming from this analysis are the degree to which non-natives are likely to increase, and the degree to which occupation of areas where one or more of the removal methods was used has contributed to the success of these non-natives. Methods that

exclude the non-natives would be better than those that don't. Counterbalancing this concern is the obvious fact that some of the removal methods have enhanced the diversity of native species. Without management in the future that mimics these or other equivalent disturbances, the non-competitive natives on these plots will disappear as trends for the pools as a whole take over.

Comparison of methods in terms of how source pools were affected. Species by species analysis has shown that there are particular concerns that can be addressed by the combined effect of the different removal techniques on the quality of the plant communities in the pools. Did any method or methods effectively lower abundance of non-natives while at the same time enhancing natives? Were such methods better or worse in this regard than the reference samples from the unmodified plots? We address these questions here.

The analysis of individual species in the previous section led us to identify fourteen native species that would potentially benefit from the habitat modification associated with removal of seed or soil. We refer to them in this section as "small natives." These included all of those in Set 1 and Set 2 of Table 3.3. We added *Downingia concolor* from Set 3 to this group; although it does not appear to be declining in all methods, it is in some, and like most others of the set, is a small annual. (*Pilularia americana* is a perennial, but is very small in size.) After establishing this group, we compared the results with analysis for all native wetland annuals, and the same patterns emerged (not shown).

Fig. 3.14 shows that the combined relative cover of the species in the group of small natives was higher in all removal methods than on reference plots in year 1 following removal of inoculum (1995). By year 2, values had dropped, but still exceeded those of the reference plots. There was a statistically significant effect of "method" for relative cover (Table 3.4). Effects for "system" and "year" were also significant. Highest cover for the small natives in 1996 was on the open habitat of Fill, with Exc showing high values as well.

In richness of small native species (Fig. 3.15), the removal methods all had higher average numbers per sample than reference plots. As with relative cover, the richness was higher for Fill than the other two methods, and the statistical analysis showed the effect of "method" to be significant (Table 3.4). All removal methods enhanced both cover and diversity of important native plants, and Fill was the best method overall for enhancing small native plants.

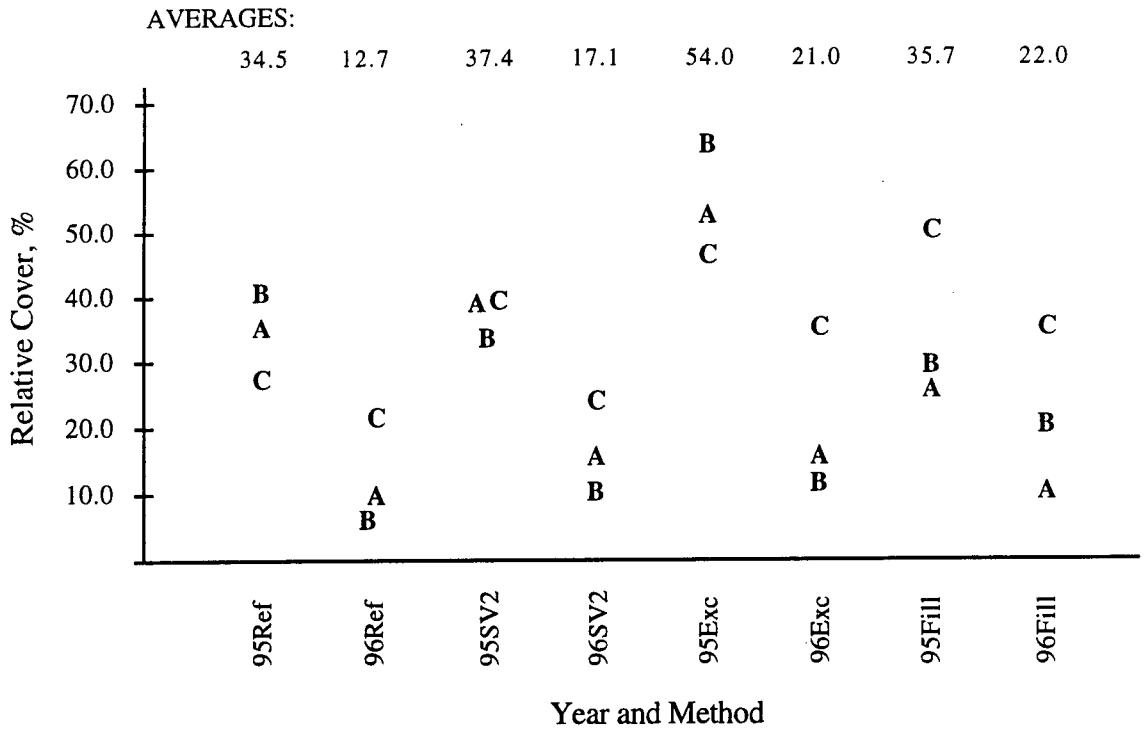

Figure 3.14. Relative cover values for the set of fourteen small native species identified as most affected by the lack of disturbance in pools. Abbreviations: reference plots=Ref, scrape/vacuum year 2=SV2, excavations=Exc, and filled plots=Fill. Values for methods in each system are plotted with their respective letters: A, B, and C.

Table 3.4. P-values for analysis of variance.

Variable	P-value Method	System	Year
Rel. Cov. Small Natives	0.0011	0.0026	0.0001
Rel. Cov. Large Natives	0.0001	0.1751	0.0486
Rel. Cov. Successful Non-natives	0.0001	0.2710	0.0001
Richness Small Natives	0.0006	0.0041	0.0001
Richness Large Natives	0.3785	0.0001	0.9792
Richness Successful Non-natives	0.0043	0.0696	0.0008

A different picture emerges when the effect of the methods on six other native species from Set 3 (excluding *Downingia concolor*) in Table 3.3 is considered. We refer to these species in this section as "large natives." As shown in Fig. 3.16, these species did noticeably better on reference sites than on removal plots. Exc and Fill had the greatest adverse effect. In contrast with the small natives, however, relative cover values were rising slowly, supporting the idea that these species are much less likely to disappear from

the pools. With respect to average number of species per sample for large natives, there was no significant difference among the methods (Fig. 3.17). None of the species occurred in more than four pool systems, making richness low to begin with.

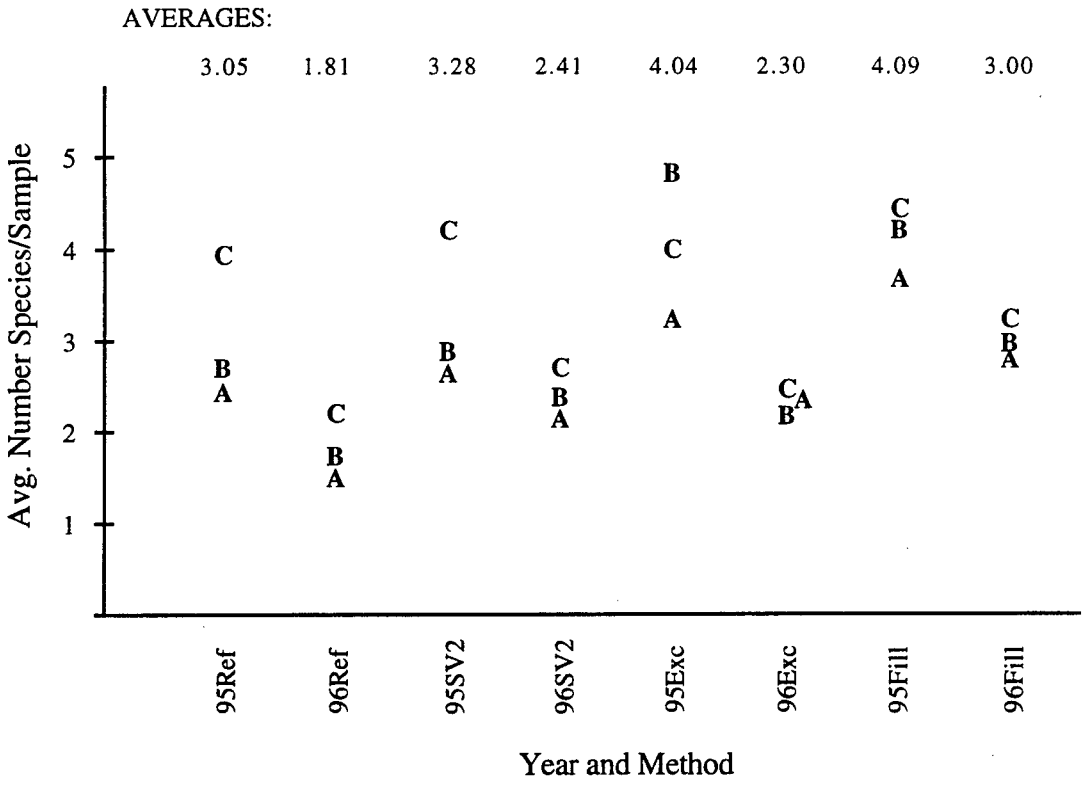

Figure 3.15. Average number of species per sample for the fourteen small native species identified as most affected by the lack of disturbance in pools. Abbreviations: reference plots=Ref, scrape/vacuum year 2=SV2, excavations=Exc, and filled plots=Fill. Values for methods in each system are plotted with their respective letters: A, B, and C.

When both affects on large and small natives are considered, the removal methods are seen to be equivalent. All exceeded the reference samples in cover and richness for small natives, but had lower values for the large ones. Exc ranked slightly lower than the other methods in all measures of success for natives except that it was higher in relative cover of small natives than SV2. Fill ranked above Exc in all categories, and below SV2 in both measures for large natives. Importantly, none of the removal methods had a direct adverse affect on native vernal pool plants.

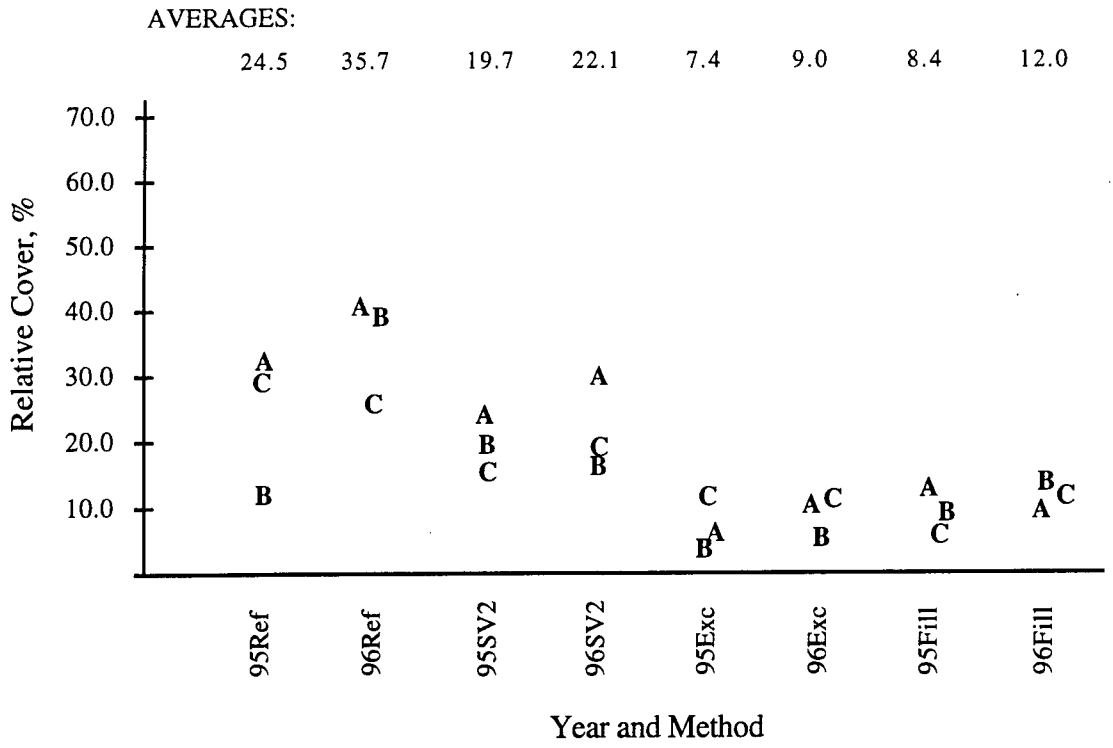

Figure 3.16. Relative cover values for set of six large native species that appear to be maintaining populations in the pools. Abbreviations: reference plots=Ref, scrape/vacuum year 2=SV2, excavations=Exc, and filled plots=Fill. Values for methods in each system are plotted with their respective letters: A, B, and C.

A second consideration in performance of the removal methods was the degree to which they encouraged or discouraged non-native wetland species. We noted in the previous section that the SV1 plots in the year they were cleared developed cover values for a number of non-natives that were higher than those of reference plots, and higher than those experienced by the SV2 plots a year later. Using this information, we listed three non-natives as Set 5 of Table 3.3 that all showed potential to invade clear areas within pools. An additional Set 6 consisted of four natives with populations growing in the pools independently of events in 1994. These seven species we combined here for analysis into a group of "successful non-natives."

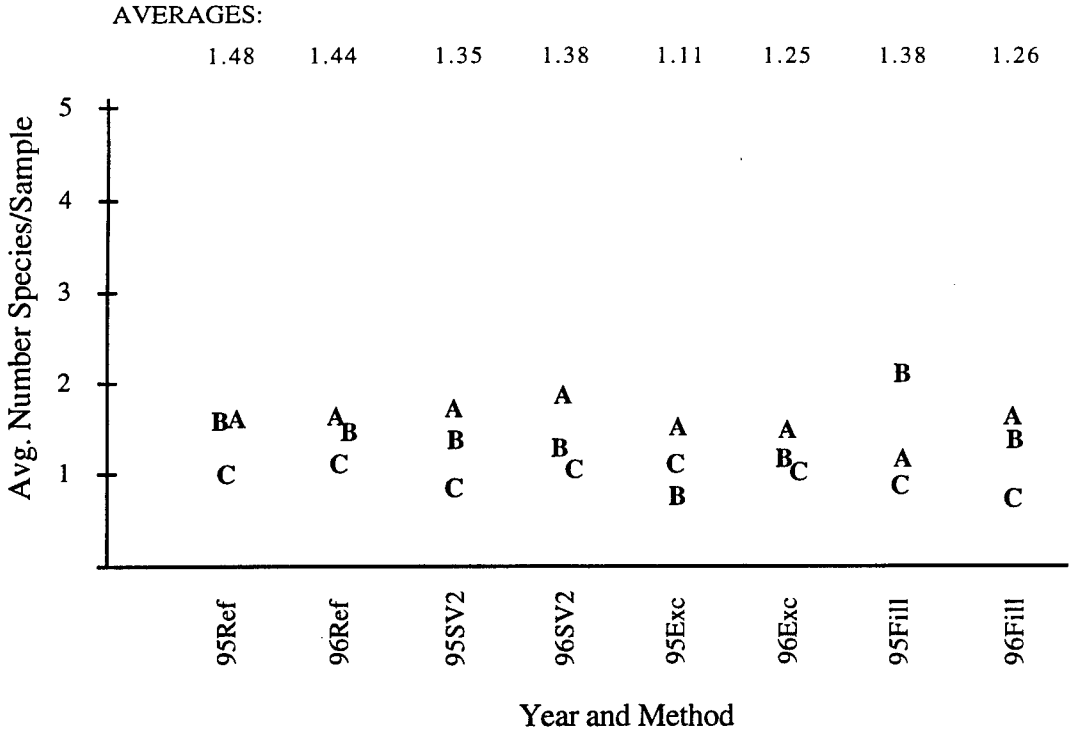

Figure 3.17. Average number of species per sample for set of six large native species that appear to be maintaining populations in the pools. Abbreviations: reference plots=Ref, scrape/vacuum year 2=SV2, excavations=Exc, and filled plots=Fill. Values for methods in each system are plotted with their respective letters: A, B, and C.

The removal methods differed strikingly in the degree to which they enhanced these successful non-natives. In relative cover (Fig. 3.18), the value for this group rose somewhat on reference plots from 1995 to 1996 (24.1% to 31.2%). The Exc method showed similar but slightly lower percentages. These plants on SV2, however, experienced an increase from 31.5% to 44%, and on Fill they jumped from 21.9% to 47.7%. The effect of "method" on relative cover, as well as the effects of "year" and "system", were statistically significant (Table 3.4). Clearly the nature and degree of the disturbance on SV2 and Fill led to increase in the cover of non-natives.

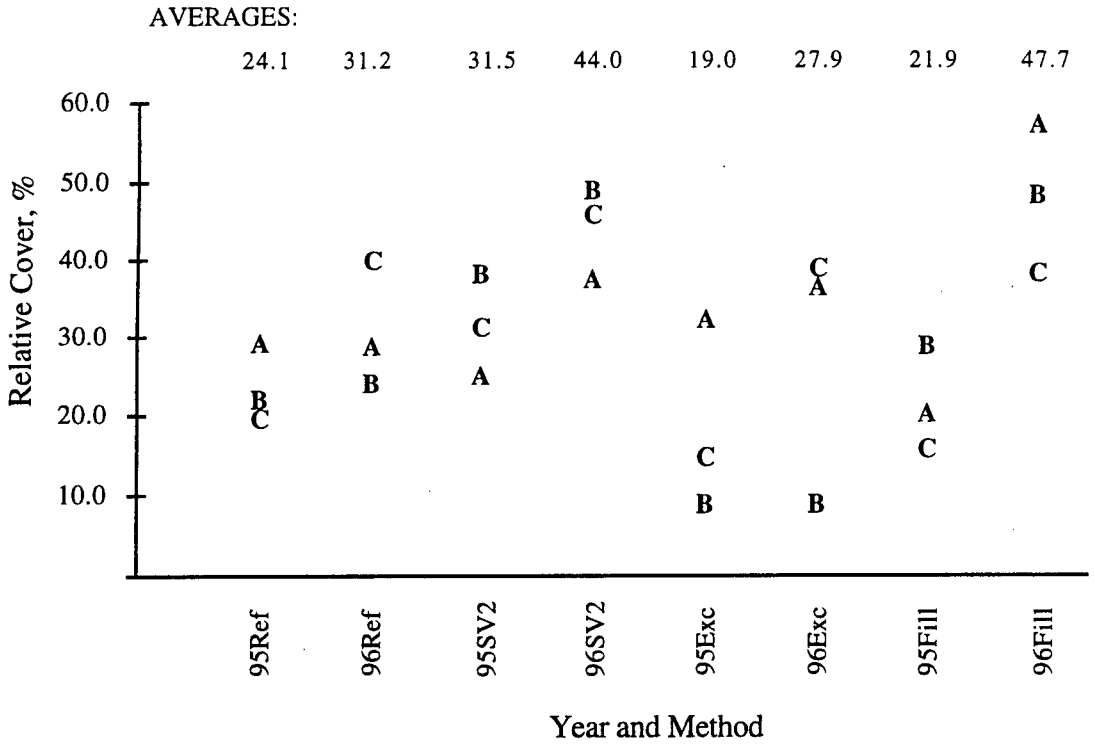

Figure 3.18. Relative cover values for the seven successful non-native species identified as most likely to invade and/or persist in pools. Abbreviations: reference plots=Ref, scrape/vacuum year 2=SV2, excavations=Exc, and filled plots=Fill. Values for methods in each system are plotted with their respective letters: A, B, and C.

In the number of successful non-natives in the average plot, the same pattern emerges (Fig. 3.19). Exc experienced almost the exact same increase in species richness for this group as did the reference plots (about 2.7 species per plot to 3.0), SV2 reached a level of 3.5 species per plot in 1996, while Fill jumped to 4.0. The richness data showed significant effects for "method" and "year", but not "system" (Table 3.4).

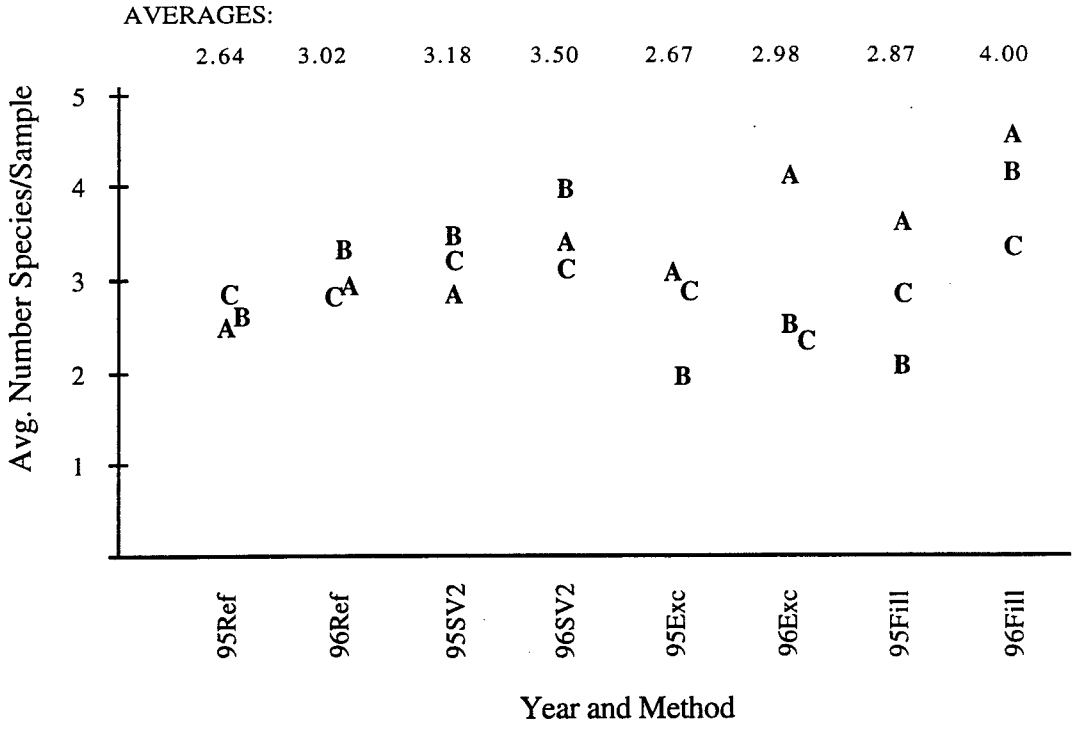

Figure 3.19. Average number of species per sample for the seven successful non-native species identified as most likely to invade and/or persist in pools. Abbreviations: reference plots=Ref, scrape/vacuum year 2=SV2, excavations=Exc, and filled plots=Fill. Values for methods in each system are plotted with their respective letters: A, B, and C.

Despite the fact that both SV2 and Fill enhanced cover and richness of small native plants, they both were inferior to Exc as methods for removing materials from natural pools to transfer elsewhere because they enabled non-native wetland plants to gain a foothold in the pools or rise to higher individual and collective levels of abundance. Clearly, Exc is the best method for performing removal from natural pools. The other two methods could prove in the long run to be equivalent if additional monitoring shows that over time they lose the adverse properties we discovered. In addition, new experiments could be performed on modifications of either of these methods to reduce their adverse affects. Until additional data are available, however, it would be better to use excavation as the means for removing inoculum and to leave the excavations alone once they have been made.

LITERATURE CITED

Reed, P. B., Jr. 1988. National List of Plant Species That Occur in Wetlands: 1988 California (Region 0). U.S. Fish and Wildlife Service Biological Report 88 (26.10)

Chapter 4-Aquatic Invertebrates and Physical Factors of the Hydrated Pools

INTRODUCTION TO MAJOR QUESTIONS

Vernal pools support a variety of animals, among which are short-lived aquatic invertebrates that are integral parts of an ephemeral ecosystem when the pools are hydrated. Many of these, such as microcrustaceans like copepods, survive the summer drought as cysts and then quickly hatch to grow and reproduce before the pools dry. Invertebrates include herbivores that filter or trap unicellular algae in the water column or scrape filamentous algae from pool bottoms. Numerous predators, like flatworms and larger microcrustaceans, eat small herbivores, and larger invertebrates like diving beetles and back swimmers are predators at the top of a specialized food chain. Although the ecological relationships of all of these invertebrates to each other and to other parts of the aquatic and surrounding terrestrial ecosystem are not well known, a healthy component of invertebrates is necessary for full functioning of vernal pools. We therefore included study of them in our experiment.

We studied invertebrates in the same pools as other aspects of our work: three systems of pools each with a source pool or set of pools matched with five created pools (system A: source pool TR5, created pools A1-A5; system B: TR17 and B1-B5; system C: TR1-TR4 pooled as source and C1-C5). In the created pools of each system, one was left unmodified as a control, the second was inoculated in the Fall of 1993 with materials scraped and vacuumed from the source pool (the Vac1 treatment), and a third was inoculated with scrape/vacuum materials in Fall of 1994 (Vac2). Also in 1994, we inoculated the fourth pool with intact blocks of sod from source pool bottoms (Blocks), and the fifth pool with soil from the source (Soil).

Using a small plankton net in the water column and on pool bottoms, we sampled invertebrates in source pools and created pools every two weeks during the wet season from 1993 through 1996. Preserved samples were studied at a later date to identify

organisms and determine how many of each were present in the pools. We also took physical data on the pools including pH, temperature, total dissolved solids and turbidity. We wanted to know:

1. if aquatic invertebrates utilized the created pools in numbers equivalent to those in source pools;

2. if waiting one year before inoculating a pool would lead to greater success than introducing source materials in the year of construction;

3. if one of three methods of inoculation produced greater success in created pools; and

4. if physical factors of pH, temperature, turbidity, and total dissolved solids differed systematically between source and created pools.

LIST OF MAJOR CONCLUSIONS

1. Created pools were successful for some invertebrate taxa but not others. Of 31 taxa tabulated, 22 were abundant enough to allow their use in evaluating success of the different inoculation methods. In comparison with the source pools, eight of these taxa were highly successful in created pools, five were moderately successful, and nine exhibited low success. Taxa known to live predominantly in the water column were much more successful than those that live on pool bottoms. Time may be necessary for the created pools to develop a normal benthic environment.

2. Inoculation of created pools is not necessary for them to develop reasonably diverse invertebrate faunas, but it helps selected species. Each of the uninoculated control pools was colonized by a number of insect taxa. Nearly all of the microcrustaceans identified to the level of species (five of six copepods and six of seven cladocerans, excluding two with very limited data) colonized the control pools, and a few were more successful in control pools than in source pools. Despite this, selected species, such as the benthic, harpacticoid copepod, *Attheyella dogieli*, and the benthic, macrothricid cladoceran *Macrothrix hirsuticornis*, were absent from controls, and the former occurred only in one created pool.

3. For those taxa that did succeed in inoculated pools, the pattern of seasonal abundance, such as having stationary numbers or showing steady increase, matched that of

the source pools. These animals were clearly extracting resources from the created pools in ways that allowed them to carry out their life cycles.

4. Waiting a year to inoculate pools as opposed to doing so in the year of construction does not increase success for invertebrates.

5. The Soil inoculation method produced greater success for invertebrates than other methods. The number of invertebrate taxa, similarity to sources, and difference from uninoculated controls were all higher in the Soil treatment. In the second year following inoculation, the Soil pools had 18.3 invertebrate taxa on average compared with 14.7 for Vac2 and 13.7 for Blocks. The larger source pools averaged 24.3.

6. Created pools by year three had about half the amount of total dissolved solids as sources. This may or may not be important for invertebrates. Temperatures were higher in the source pools, probably because created pools all had a deep end and thus a greater average depth to dampen fluctuations. Turbidity and pH did not show important differences by year 3.

METHODS

Using a plankton net measuring 12.1 cm in diameter, Doug Eakins sampled invertebrates at two-week intervals in years 1 (1993-94), 2 (1994-95), and 3 (1995-96). We have expressed the densities of organisms as numbers per meter of net tow. Given the dimensions of the net, each meter had a volume of 11.4 liters, thus "number/m" can be divided by 11.4 to get "number/l." Data for year 1 were used primarily to compare the Vac1 (inoculation at the time of construction) vs. Vac2 methods (inoculation one year later). Year 2 and year 3 data were used for the main analysis of the effect of different inoculation methods on success. Tabular summaries of the data and information on seasonal trends appear in Appendix D.

Each field day, Doug sampled a representative portion each pool, judged to be approximately 10% of its surface area. He cast the plankton net from the shore, thus avoiding the physical disturbance of the pools that wading would have caused. He pulled the net along the bottom and through the water column sampling each apparent microhabitat. The net was thoroughly rinsed in clean water before moving from one pool to another.

Sampling effort was essentially equivalent in all of the created pools, and smaller on a per pool basis than for the two large source pools (TR5 and TR17). This was necessary to reflect the size and potential habitat diversity of these source pools, and means that a given created pool would be expected to have a somewhat lower total number of taxa than the source just due to the sampling effort. The sampling effort among created pools was essentially equivalent, however, as shown in Table 4.1.

For a given pool and sampling date, organisms were preserved in 70% ethanol in a single jar. Later, they were identified under a dissecting microscope, generally to family, and counted. A subsampling procedure was used to count animals that were very abundant. To obtain some information on species, a subsample of all of the copepods from year 2 was sent to Janet W. Reid, a noted expert on this taxon. Brenda Hann, an expert on the cladocera, identified our 1995 and 1996 specimens to species in this group. At the species level, these colleagues helped us determine presence or absence of each species in each pool and sampling date.

Table 4.1. Sampling effort for invertebrates in years 2 and 3, for dates used in the analysis of treatment effects.

System	Year	Pool	Treatment	m net pull
A	2	A1	Vac1	78
		A2	Vac2	78
		A3	Control	69.5
		A4	Blocks	78
		A5	Soil	75
		TR5	Source	153
	3	A1	Vac1	81
		A2	Vac2	81
		A3	Control	67
		A4	Blocks	81
		A5	Soil	72
		TR5	Source	159
B	2	B1	Blocks	81
		B2	Vac2	78
		B3	Control	78
		B4	Vac1	78
		B5	Soil	75
		TR17	Source	141.5
	3	B1	Blocks	81
		B2	Vac2	78
		B3	Control	78
		B4	Vac1	81
		B5	Soil	81
		TR17	Source	114.5
C	2	C1	Control	78
		C2	Vac2	78
		C3	Vac1	78
		C4	Soil	78
		C5	Blocks	78
		TR1	Source	83
		TR2	Source	68
		TR3	Source	54.75
		TR4	Source	69.75
	3	C1	Control	81
		C2	Vac2	81
		C3	Vac1	75
		C4	Soil	75
		C5	Blocks	81
		TR1	Source	90.75
		TR2	Source	67.25
		TR3	Source	71.25
		TR4	Source	66

Hydrologic conditions were similar in 1995 and 1996 (data in Appendix A), but were much drier in 1994. Pools in year 1 were all full on only two sampling dates (Table 4.2) but six dates from Feb. 4 through Apr. 15, 1994, were included in the analysis. All of the Vac1 pools (A1, B4, and C3) as well as the Vac2 pools (A2, B2, C2) were hydrated on all six dates. For years 2 and 3, hydration extended over a much longer time, and 9 dates were used each year: Dec. 17, 1994-Apr. 8, 1995 for year 2 and Dec. 16, 1995-Apr. 6, 1996 for year 3.

Prior to sampling each pool, a measurement was made of temperature (°C), pH, and total dissolved solids (TDS, mg/l) using a Corning M90 portable meter. Turbidity was measured by placing a stirred aliquot of water in a Spectronic 20 spectrophotometer in the lab and measuring percent transmission at 450 nm (Brower, Zar, and von Ende 1990, p. 49). Technical difficulties prevented measurement of turbidity in year 1, and of the other three factors in source pools that year. By the time the methods were perfected that year, the source pools were dry.

Table 4.2. Sampling dates for invertebrates and pool conditions on those dates.

Dates Year 1:93-94	Pool Conditions	Dates Year 2:94-95	Pool Conditions	Dates Year 3:95-96	Pool Conditions
4 Feb	TR1, 5, 17 dry	17 Dec	All hydrated	16 Dec	All hydrated
18 Feb	All hydrated	29 Dec	All hydrated	30 Dec	All hydrated
4 Mar	All hydrated	16 Jan	All hydrated	14 Jan	All hydrated
18 Mar	TR 1-5, 17, A3 dry	30/31 Jan	All hydrated	28 Jan	All hydrated
1 Apr	TR 1-5, 17, A3, B4 dry	13 Feb	All hydrated	11 Feb	All hydrated
15 Apr	TR 1-5, 17, A3, B4 dry	25 Feb	TR2, A3 dry	25 Feb	All hydrated
22 Apr	TR 1-5, 17, A3, B4 dry	11 Mar	All hydrated	10 Mar	All hydrated
30 Apr	TR 1-5, 17, A3, B4 dry	26 Mar	All hydrated	24 Mar	TR2, 4 dry
14 May	TR 1-5, 17, A3, B4, C2 dry	8 Apr	TR2, 4 dry	6 Apr	All hydrated
		21 Apr	TR 1-5, 17, A3, A5 dry	21 Apr	TR1-5, 17, A3, A5 dry
		7 May	TR 1-5, 17, A3, A5, B4, C2-4 dry		

RESULTS

Life histories of invertebrates and qualitative evaluation of success. We tabulated data for 31 taxa at family level or higher, and species within two groups of crustaceans (copepods and cladocerans) were identified by experts. All of the quantitative data are based on higher taxonomic levels. Appendix D gives average annual densities for each taxon in each pool over three years, and graphs seasonal trends in density for each taxon. Table 4.3 lists these 31 taxa along with an overview of their life histories and a qualitative summary of their abundance and response to the experiment.

Some of the vernal pool invertebrates, including all of the crustaceans, undergo their entire life cycles in the pools, leaving behind resistant stages such as eggs or cysts after pools have dried. Others, including most of the insects except the collembola, invade the pools anew each season as terrestrial, flying adults that lay eggs in the water. Both components of the fauna are essential for complete functioning of the ecosystem.

Table 4.3. Overview of life histories of invertebrates and the degree to which they were affected by the transplant experiment. These animals were identified to different levels in the taxonomic hierarchy. For simplicity, we have used common names. Much life history information is from Pennak (1989), Thorp and Covich (1991), and Merritt and Cummins (1984).

flatworm

Primitive organisms. More than one species is probably present. They are prominent members of the community, and actively prey with mucous or stylets on small invertebrates like microcrustaceans. They also scavenge dead or wounded animals. May have just one sexual generation per season, and may reproduce asexually by fission.

Transplant effect. Present in all pools and appear early in the season. Much less common in controls, suggesting that propagules come primarily from existing pools. Generally increased in third year in inoculated pools.

nematode

Simple worms in body form that are diverse in their ecology. The sampled forms are free-living, less than 1 cm in length. They prey on other animals, usually with a stylet, or microorganisms with mucous. Permanent residents of the pools. Eggs contain first stage juveniles when laid, and this is the resting stage in the dry season.

Transplant effect. Much more common in source pools than inoculated, and nearly lacking in controls, which suggests that transplanted eggs are the source. Table in Appendix D shows much greater success with the soil treatment than others. Did not increase and may have decreased in year 3.

Table 4.3, life histories continued.

gastropod

These are the snails, a group that is common in many aquatic habitats. They graze on the film of microscopic algae that forms on other surfaces, or possibly on some plants directly. Resting stages for the species in the pools are not known.

Transplant effect. In the study, they were uncommon, generally limited to source pools, and not present in any of the controls. In the two inoculated pools where they were found (system B/Vac2 and system C/Blocks) they occurred in year 2 but not year 3.

aphanoneurid worm

Very small worms, related to annelid worms or a distinctive group (Phylum Annelida, Order Aphanoneura, Family Aeolosomatidae in Thorp and Covich, 1991, p. 417). Generally a few mm long or attached together end to end in chains, since they reproduce by fission. Sexual reproduction may be rare. Feed on microorganisms and particulate matter by suction and by "vacuuming" food into the mouth with cilia. Form a resistant mucous cyst around themselves in the dry season.

Transplant effect. Quite common residents in source pools; lacking in controls but did appear in the year prior to inoculation in some pools. Did not persist into year 3 in any inoculated pool.

oligochaete

Aquatic earthworms similar in life history to terrestrial species. Probably permanent aquatic residents not found outside of pools. Eat by ingesting soil and detritus and digesting organic matter and microorganisms that it contains.

Transplant effect. Much more common in source pools than others. Appeared in one control and two inoculated pools in year 2 but did not persist into year 3.

tardigrade

These tiny "water bears" are in a phylum of their own. Most can survive complete desiccation as resistant cysts around the organism with internal water removed. Use piercing stylets to break outer layers of moss and algae and suck out fluids. Probably a truly aquatic resident.

Transplant effect. Very uncommon in all pools. Found in source pool of system A and the Vac1 pool. Found in years 2 and 3 in this Vac1 pool.

calanoid copepod

These small microcrustaceans have long antennae that reach nearly the length of the body. They swim with these antennae and their feet, and either filter small organisms from the water column or actively capture larger animals. Adults and juveniles can survive as cysts in the dry season, and drought resistant eggs can be produced.

Transplant effect. They were most abundant in all created pools of system A, even more so than in the source pool. In systems B and C, their density varied widely from pool to pool, and was often higher in year 3 than in year 2 in created pools. The widespread distribution that includes control pools suggests

Table 4.3, life histories continued.

that their drought-resistant stages are common in soils beyond the source pools themselves.

cyclopoid copepod

These microcrustaceans swim with antennae and feet, generally in the water column. They eat by attacking invertebrate prey and do not filter-feed. Resistant stages are as for the calanoid copepods.

Transplant effect. They were abundant in all pools, including controls, and had more equal numbers among pool systems than the calanoids. Their presence in control pools suggests that, as for calanoids, their eggs or cysts may be broadly distributed beyond source pools.

harpacticoid copepod

These copepods have bodies that are little tapered, a distinction from the other two copepod groups. Their antennae are short. They feed among decomposing matter on the bottoms of pools, eating detritus, algae, and some small, live benthic organisms.

Transplant effect. They were common only in the source pools of systems A and C, and occurred in small numbers in three inoculated pools in year 2 and two in year 3.

chydorid cladoceran

One of four groups of "water fleas" found in the pools. The head has a single eye, and animals use antennae for locomotion. A carapace covers the body. All cladocerans use sieves on their flat legs to trap microscopic and sometimes larger food. Cladocerans survive the drought period as resting, sexually-produced "eggs" (young embryos) in diapause and surrounded by a dark modified portion of the female's carapace called the "ephippium." Each ephippium contains one or two young. Chydorids live in the benthos, and may crawl with their rear spines and antennae.

Transplant effect. Members of this group were found in small numbers in the Vac1 treatment and two sources in year 1. In year 2, they appeared in controls, but were more abundant in the Soil treatment. Numbers fluctuated from year 2 to 3, but remained moderately high overall. Although the group invaded controls, inoculation, especially by the Soil treatment, seems to have accelerated development of populations.

daphniid cladoceran

One of four groups of "water fleas" found in the pools, sharing the basic structural and reproductive characteristics described for chydorids. Daphniids live in the water column, and are one of the main feeders on microscopic algae.

Transplant effect. Common in source pools. In system A, they had invaded controls by year 2 and continued in year three, but they had not invaded controls in either systems B or C by year 3. They were found in inoculated pools of all systems except Blocks in system C, and numbers went up or down in individual pools from year 2 to 3. Inoculation appears to have been essential in systems B and C.

Table 4.3, life histories continued.

macrothricid cladoceran

One of four groups of "water fleas" found in the pools, sharing the basic structural and reproductive characteristics described for chydorids. Marcothricids, like chydorids, live in the benthos.

Transplant effect. They were not noted in year 1 in any pool, and had invaded controls in systems B and C in year 2 as well as being present in sources and all inoculated pools. Like most of the microcrustaceans, there probably are resting stages of this group throughout soils of the area.

moinid cladoceran

One of four groups of "water fleas" found in the pools, sharing the basic structural and reproductive characteristics described for chydorids. Moinids are planktonic.

Transplant effect. Presence in the created pools was notably independent of sources: they appeared in small numbers in the control and some inoculated pools in system A but were not present in the source, and populations were orders of magnitude larger in controls and inoculated pools in systems B and C in year 2. It may be that the open environment of the created pools is particularly favorable to moinids under some circumstances.

ostracod

These very small "seed shrimps" are microcrustaceans with oval, calcium carbonate shells on either side of the body, nearly obscuring the rest of the animal. They have an egg that can withstand desiccation due to layers of chitin and calcium carbonate. In addition, developmental stages ("instars") can survive as drought resistant cysts, like those of the copepods. All ostracods live in the bottom sediments, some are able to swim with their antennae to move short distances and others are limited to crawling with antennae and one pair of legs. They eat algae and detritus.

Transplant effect. Although some individuals were found in control and uninoculated pools in the first year, densities were much higher in sources and the inoculated Vac1 pools. Densities were generally much higher the first year after inoculation than the second. Controls in year three had good densities, so inoculation does not appear necessary for this taxon.

baetid mayfly

The mayfly nymphs of this family typically scrape algae and detritus from plant surfaces and pond bottoms. Adults fly and live on land for short periods as they lay eggs in water. Eggs may be capable of withstanding drought in some species.

Transplant effect. The fact that they were sampled in small numbers late in the season, from source pools, suggests that they hatched from eggs laid during earlier parts of the year. Nymphs may or may not have metamorphosed in the pools we studied.

Table 4.3, life histories continued.

libellulid odonatan

The nymphs of this dragonfly family typically hide on the bottom of a body of water and capture large prey like annelids and tadpoles by sudden extension of large jaws.

Transplant effect. Sampled in small numbers late in the season, from source pools and the Soil treatment of system A. Must have hatched from eggs laid during earlier parts of the year in these pools. The species probably uses larger, more permanent bodies of water, and these nymphs probably died as pools dried out.

chironomid dipteran

Chironomids, or true midges, have small flying adults that lay eggs in water. The larvae feed and metamorphose into adults most years. Most species have larvae that live in the bottom muds and filter microscopic organisms and detritus from the water. May have drought resistant eggs or larvae.

Transplant effect. They were abundant in essentially all pools, including controls.

culicid dipteran

Mosquitoes. Larvae hatch from eggs laid in the water, and filter algae and very small organisms from the water with mouth brushes. They spend much of the time at the water's surface because they breathe air. Only the larval and pupal stages are spent in the water, and the organisms exist as terrestrial adults through the dry season to lay eggs later after rains.

Transplant effect. The taxon was found almost entirely in the source pools.

dixid dipteran

The larvae of these dixa midges resemble mosquito larvae and filter food from near the water surface with brushes. They are common in very small bodies of water. Only the larval and pupal stage take place in pools, and, like culicids, the populations probably persist on land as adults.

Transplant effect. The dixids were only found in small numbers in three source pools late in year 3. thus the vernal pools are used opportunistically for this stage of the life cycle along with other ephemeral bodies.

tabanid dipteran

These horseflies have larvae that hatch from eggs out of water and fall into the water where they spend several years maturing.

Transplant effect. Although found in both years and in several pools, they probably represent forms that will not complete their life cycle in the vernal pools.

noctuid moth

A small number of moths in the family Noctuidae have aquatic larvae, though most moth caterpillars are terrestrial. Adults of the aquatic forms live on land like other moths.

Table 4.3, life histories continued.

noctuid moth, continued

Transplant effect. Members of the family were found in small numbers in two source and one created pool.

collembolan

These are the tiny "springtails" that often possess a two-parted furcula, or tail, with which they jump. Most collembola feed on fungi, algae, and detritus. The aquatic species present in the pool are probably permanent residents that survive in the dry season as eggs or encysted young.

Transplant effect. They appeared early in the season of both years, including in control pools.

corixid hemipteran

These aquatic insects are referred to as "water boatmen." They swim by means of fringed hind legs, hold onto things with claws on the middle legs, and scoop up detritus and the organisms it contains with front legs. They may also pierce plants and suck out fluids. The film of air around their bodies absorbs oxygen from water, which they breathe as air. Adults are strong fliers.

Transplant effect. Corixids were most abundant in source pools, but appeared regularly in controls as well as uninoculated pools in year 1. These data suggest that they survive the dry season as adults away from pools, possibly in other bodies of water, and invade pools anew each year as adults lay eggs in the water.

notonectid hemipteran

These "back swimmers" actually do swim all of the time on their backs. They capture small crustaceans and insect larvae with their front feet and suck out the body fluids from their prey. They often rest upside down at the water's surface, and carry a bubble of air on their venter when they dive. They swim by means of fringed hind legs.

Transplant effect. The taxon was often as abundant in control pools as in sources, which suggests that notonectids survive the dry season as terrestrial adults away from pools, possibly in other aquatic habitats, and lay eggs in the pools each year.

curculionid beetle

This group is the weevils, which have larvae that bore into plants. A few species have legless aquatic larvae and terrestrial adults.

Transplant effect. This taxon was found only in the source pool of system A in year 1.

dytiscid beetle

These are the predaceous diving beetles, and both larvae and adults are voracious predators on aquatic invertebrates and tadpoles, which they capture with large jaws. They pupate on land and adults return to water. Larger larval stages and adults breathe air, and adults can fly. Whether the vernal pool forms have a resting stage in dry pool sediments isn't known.

Table 4.3, life histories continued.

dytiscid beetle, continued

Transplant effect. They were lacking in controls in years 2 and 3, but were found in controls and some inoculated pools in year 1. By year 3, some inoculated pools had the taxon, but in smaller numbers than in source pools. Adults probably fly to other aquatic habitats when pools dry up.

haliplid beetle

These are the crawling water beetles, very small insects usually less than 5 mm long. Larvae and adults are fully aquatic, although adults must maintain an air supply under the wing covers and portions of the hind legs. Both forms are herbivores of aquatic plants. They pupate on dry mud and return to water as adults. Adults can fly to move to new habitat.

Transplant effect. Only a few individuals were found, and only in source pools.

hydrophilid beetle

This group of beetles is fully aquatic, and individuals of some species are large. Adults eat algae and detritus from pool bottoms but larvae are predators with large jaws. Adults and larvae of most species breathe air at the water's surface. As with the other aquatic beetles, adults can fly, and larvae move out of water to pupate.

Transplant effect. The taxon was uncommon in controls, most abundant in sources, and, among inoculated pools, found only in Blocks and Soil. This pattern suggests that the beetles were transported from sources to inoculated pools in some form.

staphylinid beetle

These beetles, known as "rove beetles," are probably semiaquatic. Little is known about them.

Transplant effect. They occurred in very small numbers in source pools of systems B and C.

oribatid mite

These small mites belong to a large group of soil mites, and there are a few aquatic species. They differ from water mites in having a teardrop shape due to different head structures. Food is fungi, algae and detritus.

Transplant effect. They appeared in small numbers over two years in the control pools in system B, but were not in controls of systems A or C. In these latter two systems, as well as in system B, they were present in source pools in years 2 and 3 and in several inoculated pools, most regularly Soil. There appears to have been some resting stage in source pools that was transferred by inoculation.

water mite

These are round, often colorful tiny mites that swim or crawl over vegetation. The group is very diverse. Adults lay eggs in water, and the larva spends a good part of its life as an ectoparasite on aquatic insects. Since some of these

Table 4.3, life histories continued.

water mite, continued

hosts fly to new pools, the larvae may disperse away from their natal pool. Larvae transform into an adultlike nymph that lacks sexual organs. It, like the adults it becomes, is a predator on microcrustaceans and small insects. The phase that survives the dry period is not clear.

Transplant effect. These mites were most frequent in source pools for system C. They appeared in several controls with as high a density as in treatment pools, suggesting either that propagules are broadly spread or that dispersal from pool to pool on hosts is common.

Success of a given inoculated pool depends on several factors. One is whether the drought-resistant stages of the invertebrates found in the soil survive the movement from source pools. For those species with such propagules, survival in the created pool then depends on whether biotic and abiotic conditions are adequate to support the species. For species that invade the pool anew each year, success will depend upon whether adults locate the pools and lay eggs, and whether the immature stages survive and develop in the pools. In addition to movement from source pools via transplanted materials and invasion by flying adults, we discovered that some species with resting stages in soil appeared regularly in control pools, and believe that these resting stages, which can be blown on the wind or carried on the bodies of animals, are widespread in soils of the area beyond the boundaries of the source pools. Table 4.4 lists taxa according to how they entered pools, and indicates qualitatively the degree of overall success of the taxon in inoculated pools based on the numerical tables in Appendix D.

Of 22 taxa that were abundant enough in source pools to allow evaluation of success, all were seen in at least one inoculated pool. Thirteen of the 22 taxa showed moderate to high success, including persistence into year 3. Of nine taxa with low success, three did not persist into year 3 (gastropods, aphanoneurid worms, and oligochaetes).

There is a clear pattern associated with success: organisms that survive on detritus in the bottoms of the pools, the benthos, were notably less successful than those that live largely within the water column. Table 4.5 clarifies this trend. It appears that some time may be required in created pools for a functional benthic environment to develop. In open water, populations of algae were apparently high enough to support algal grazers like calanoid and moinid cladocerans and their predators.

Table 4.4. Summary of the degree to which invertebrate taxa require transplant, along with an evaluation of their success based on data in Appendix D.

Taxon	Require Transplant?	Success
Transplant required or helpful		
gastropod	yes	low
flatworm	largely	moderate
nematode	largely	moderate
aphanoneurid worm	largely	low
oligochaete	largely	low
harpacticoid copepod	possibly	low
chydorid cladoceran	assists populations	high
daphniid cladoceran	assists populations	high
oribatid mite	assists populations	low
tardigrade	probably	too few to gauge
Transplant not required because of widespread resting stages in soil		
calanoid copepod	no	high
cyclopoid copepod	no	high
macrothricid cladoceran	no	high
moinid cladoceran	no	high
ostracod	no	moderate
collembolan	no	high
Transplant not required because some stage flies to pools or is transported in aerially		
notonectid hemipteran	no	high
chironomid dipteran	no	moderate
dytiscid beetle	no	moderate
culicid dipteran	no	low
corixid hemipteran	no	low
hydrophilid beetle	no	low
water mite	no	low
dixid dipteran	no	too few to gauge
noctuid moth	no	too few to gauge
curculionid beetle	no	too few to gauge
haliplid beetle	no	too few to gauge
staphylinid beetle	no	too few to gauge
Insects that occasionally lay eggs in pools, but may not metamorphose		
baetid mayfly	accidental in pools	not applicable
libellulid odonatan	accidental in pools	not applicable
tabanid dipteran	accidental in pools	not applicable

Summary:	Success	Number of Taxa
	high	8
	moderate	5
	low	9
	not determinable	6
	not applicable	3

Several benthic species were moderately or highly successful, including flatworms, nematodes, ostracods, chydorid and macrothricid cladocerans, and chironomid dipterans. It may be that the cladocerans in this group survive well on microscopic algae contained in

the benthos. The same may be true of ostracods. These organisms, in turn, may have supplied an adequate prey base for flatworms and other predators of the bottom zone. Organisms that depend primarily on decomposing organic matter itself may not have done so well. In any case, additional study would be required to determine when and if the benthic environment develops to an adequate degree to support the whole suite of organisms capable of using it.

Table 4.5. Invertebrate taxa from Table 4.4 listed by their primary habitat zone.

Benthic	Success	Open water	Success
gastropod	low	daphniid cladoceran	high
flatworm	moderate	calanoid copepod	high
nematode	moderate	cyclopoid copepod	high
aphanoneurid worm	low	moinid cladoceran	high
oligochaete	low	notonectid hemipteran	high
harpacticoid copepod	low	dytiscid beetle	moderate
chydorid cladoceran	high	culicid dipteran	low
oribatid mite	low		
macrothricid cladoceran	high		
ostracod	moderate		
collembolan	high		
chironomid dipteran	moderate		
corixid hemipteran	low		
hydrophilid beetle	low		
water mite	low		

Seasonal trends in invertebrate taxa. A few of the taxa showed pronounced seasonal trends, but most did not. Appendix D shows such trends for years 2 and 3, with all of the created pools, including controls, averaged for each pool system. Log values are used to allow values of different magnitude to appear on the same graphs.

Many of the small organisms with reservoirs of eggs and cysts in the soil appeared in high numbers on the first or second sampling date and had populations that showed little seasonal change. All of the copepods as well as flatworms, nematodes, ostracods, collembolans (although there is an apparent seasonal decrease in year 2), oribatid mites (also showed decline through year 2), and water mites displayed this pattern. As an example, the pattern for cyclopoid copepods in year 2 is duplicated from the appendix as Fig. 4.1.

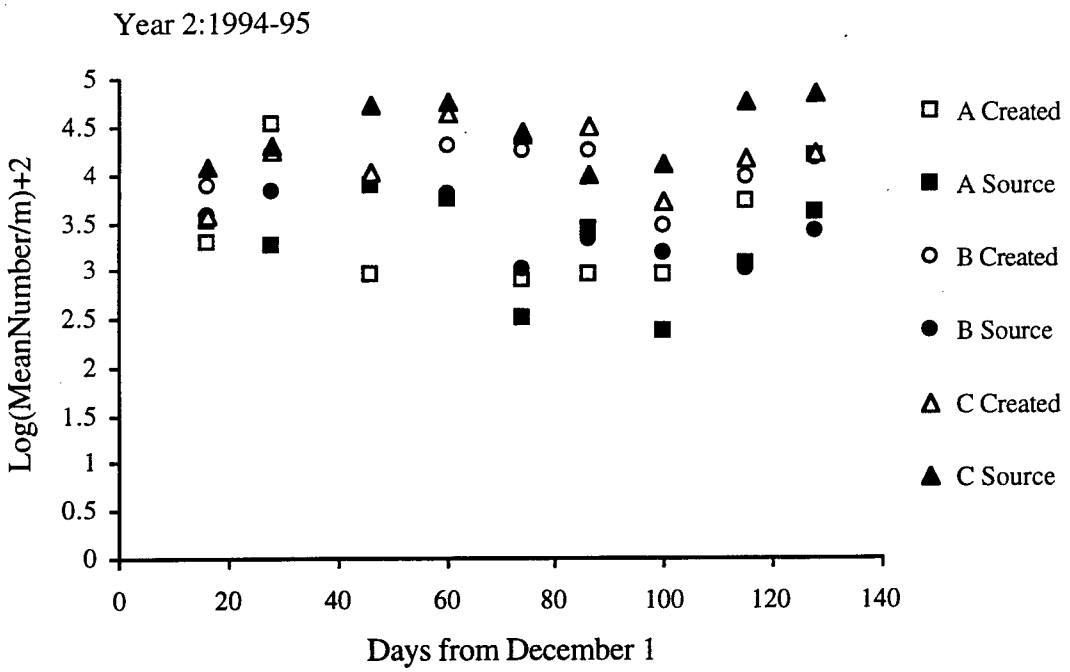

Figure 4.1. Average annual densities of cyclopoid copepods in year 2 over nine sampling dates (duplicated from Appendix D).

All of the cladocerans showed increases throughout the season in at least one of the two sample years. The strongest of these, in the chydorid cladocerans for year 2 is shown in Fig. 4.2. The cladocera are known to have longer life cycles than the copepods, and reproduce parthenogenetically early in the year as populations increase. The pattern we found matches the steady growth that one would expect to see.

Most of the insects, for which most populations develop each year from eggs laid early in the wet season by flying adults, showed weak to strong increases with the season. A typical trend is illustrated by the dytiscid beetles of year 2, shown in Fig. 4.3.

The general conclusion that results from the analysis of seasonal trends is that for invertebrate taxa that are present in the created pools, the seasonal trends in abundance are very similar to those in the source pools. Young life stages are able to extract resources from the ecosystem, to grow, and to reproduce.

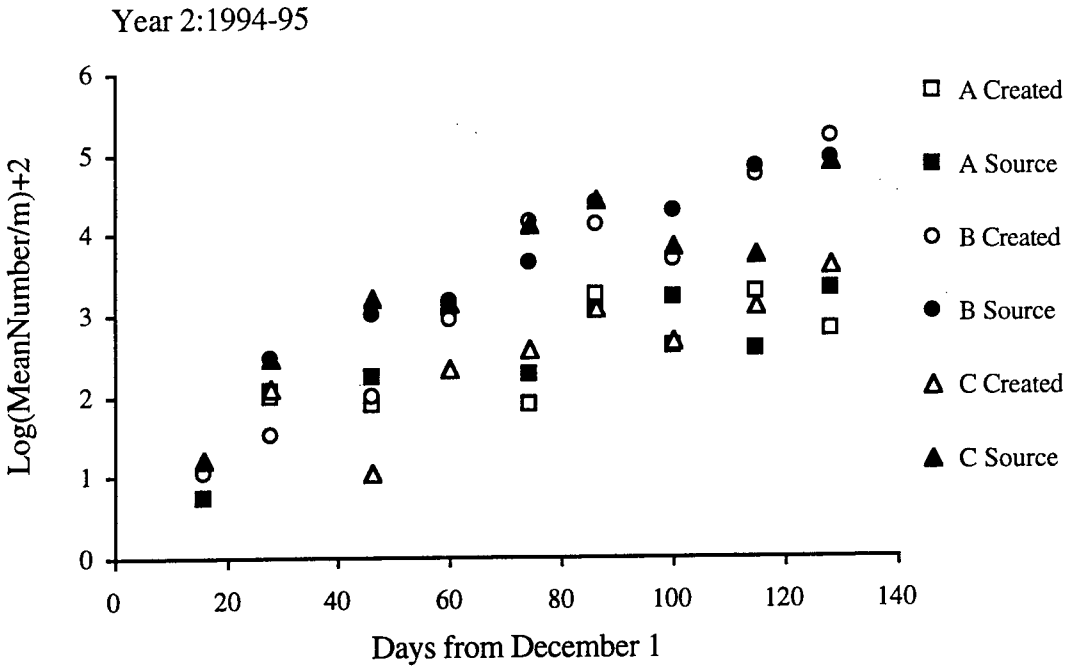

Figure 4.2. Average annual densities of chydorid cladocerans in year 2 over nine sampling dates (duplicated from Appendix D).

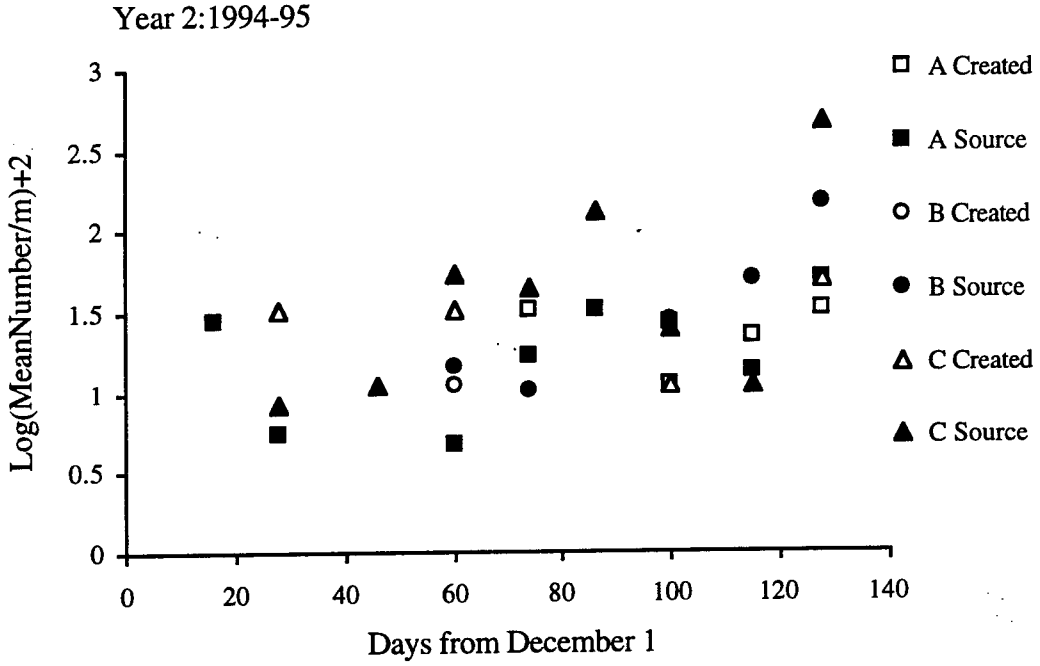

Figure 4.3. Average annual densities of dytiscid beetles in year 2 over nine sampling dates (duplicated from Appendix D).

Distribution of copepod species in the pools. Dr. Reid found six copepod species in the year 2 collections we sent her (Table 4.6; see Appendix D for dates). These included two diaptomid calanoids: *Hesperodiaptomus eiseni* (Lilljeborg, 1889), and *Leptodiaptomus tyrrelli* (Poppe, 1888); three cyclopoids *Acanthocyclops carolinianus* (Yeatman, 1944), *Diacyclops crassicaudis brachycercus* (Kiefer, 1929) *and Diacyclops lubbocki* (Brady, 1868), and the harpacticoid *Attheyella (Mrazekiella) dogieli* (Rylov, 1923). She indicated that all are previously known from west coast states.

Two of the species (*Acanthocyclops carolinianus* and *D. lubbocki*) were ubiquitous in the entire set of pools, and *H. eiseni* was nearly so. Two species were notably more common in the created pools than in source pools, including in the controls *(D. c. brachycercus* and *L. tyrelli*). This suggests that eggs and or cysts of all five of these species are broadly distributed in soils throughout the entire zone, or that just a few colonists that disperse into pools by means such as wind or birds can quickly multiply. In fact, the control pools in each system had more copepod species in them than the source pools (Table 4.6). Only one species, *Attheyella dogieli*, was found nearly exclusively in source pools, where it was present in systems A and C but not B. This is a harpacticoid species, that, as noted above, utilizes the benthos.

Distribution of cladoceran species in the pools. Dr. Hann identified eight species of cladocerans in our samples from years 2 and 3 and a possible ninth. These included four chydorids (family Chydoridae): *Alona* cf. *circumfimbriata, Alona* cf. *setulosa, Alona sp.* 3? (a possible third species), and *Chydorus* cf. *sphaericus*; two daphniids (fam. Daphniidae): *Ceriodaphnia sp.* and *Simocephalus* cf. *acutirostris*; two macrothricids (fam. Macrothricidae): *Macrothrix hirsuticornis* and *Macrothrix sp.*; and one moinid (fam. Moinidae): *Moina wierzejskii.* Table 4.7 shows the number of sample dates for which each of these species was found in each pool, and dates for each are in Appendix D.

With one exception, the information on individual species was consistent with what we concluded above about groups of cladocerans: based on examination of the macrothricids as a group, we concluded above that they were broadly spread throughout the soil and little dependent on inoculation. This phenomenon may have been due primarily to *Macrothrix sp.* (Table 4.7), because *Macrothrix hirsuticornis* did not appear in the control pools. In this instance, identification to species level showed a detail of inoculation success that was not noticed in the family-level identification.

In all other members of this group, the species patterns matched those already noted. For example, in Table 4.3 we indicated that chydorids as a group were most abundant in inoculated pools but also occurred in controls. The individual species within this group all occurred in control pools as well as many inoculated pools. The daphniids are essentially represented by a single species, *Simocephalus* cf. *acutirostris*, because *Ceriodaphnia* only occurred in one pool on one date. *S.* cf. *acutirostris* did show the pattern of being found more frequently in inoculated pools than controls. Finally, monids, like daphniids, were represented by a single species (*Moina wierzejskii*), and it was present in many sampling dates in all created pools, but not in source pools. This is consistent with our conclusion in Table 4.3 that the created pools especially favored it over the source pools. The overall species richness was very similar among all types of pools (Table 4.7).

Table 4.6. Number of sample dates in which six copepod species were found in year 2 (1994-95).

System	Treatment	Pool	calanoids		cyclopoids			harpacticoid	Total Species
			H. eiseni	L. tyrrelli	A. carolin.	D. c. brac.	D. lubbocki	A. dogieli	
A	Source	TR5	5	2	7		6	9	4
	Control	A3	6	6	6	1	2		5
	Vac1	A1	10	8	4		4		4
	Vac2	A2	11	10	5				3
	Blocks	A4	10	9	5		3		4
	Soil	A5	8	5	8		7	1	4
B	Source	TR17	2		7		5		3
	Control	B3	6		9	1	7		4
	Vac1	B4	2		9	2	9		4
	Vac2	B2	2		6		8		3
	Blocks	B1	7	1	6		9		4
	Soil	B5	5	5	6	1	9		5
C	Source	TR1			9		7	5	2
	Source	TR2			6		7	3	2
	Source	TR3	1		5		7	7	3
	Source	TR4	1		5		7	3	3
	Control	C1		2	8	2	9		4
	Vac1	C3	7	1	4	2	9		5
	Vac2	C2		1	5		10		3
	Blocks	C5		7	7		7		3
	Soil	C4	1	1	10		7		4

Table 4.7. Number of sample dates in which nine cladoceran species were found in year 2 (1994-95) and year 3 (1995-96).

System	Treatment	Pool	chydorids							daphniids				macrothricids				moinids		TOTAL SPECIES	
			Alona cf. circumfimbriata		*Alona cf. setulosa*		*Alona sp. 3?*	*Chydorus cf. sphaericus*		*Ceriodaphnia sp.*	*Simocephalus cf. acutirostris*			*Macrothrix hirsuticornis*		*Macrothrix sp.*		*Moina wierzejskii*			
			Yr2	Yr3	Yr2	Yr3	Yr3	Yr2	Yr3	Yr3	Yr2	Yr3		Yr2	Yr3	Yr2	Yr3	Yr2	Yr3	Yr2	Yr3
A	Src	TR5	1	1	4	1		7	3	1	9	7		2						5	5
A	Con	A3		1		5		2	2		3	3						1	1	3	5
A	Vac1	A1		1	1	5			1		9	7		3	1	1				4	5
A	Vac2	A2		1	1	2		4	3		9	6					1		1	3	6
A	Blks	A4			3	3					1	6				4		2		4	2
A	Soil	A5	1	1	3	5		4	4		7	6			1	1	3	2		6	6
B	Src	TR17	4	2	5	1		7	3		9	4		3	1	1			2	6	6
B	Con	B3	1	1	5	3		2	3			2				2	4	7	3	5	6
B	Vac1	B4		1	6	5		7	4		9	6		1		4	5	3	1	6	6
B	Vac2	B2	3	3	4	5		5	3		8	4		1		3	4	7	5	7	6
B	Blks	B1	4	1	4	6		6	3		8	6				3	3	1	1	6	6
B	Soil	B5	3	2	3	6		7	5		6	8		1	1	3	4	5	2	7	7
C	Src	TR1	1	2				6	5		7	7		6	3	4	1			5	5
C	Src	TR2	1	2	1	1			1											2	3
C	Src	TR3						7	5			1		2	5	3	2			3	4
C	Src	TR4						4	3		5	6		5					1	3	3
C	Con	C1	3	5	1	4		1	2							1	1	11	6	5	5
C	Vac1	C3	2	4		1		3	1			1				5	3	8	5	4	6
C	Vac2	C2	2	5		3		4	4		4			1		7	4	9	2	6	5
C	Blks	C5	1	1	2	3	1	4				1				1	7	7	9	5	6
C	Soil	C4	1	2	3	7		4			8	6		1	2	4	5	7	4	7	6

Effect of transplanting materials in the year of construction vs. one year later. The Vac1 treatment received materials from source pools in the year of construction, while Vac2 received them by the same method after the pools had been through the first winter. We analyzed the total number of taxa and the densities of individual taxa to determine if allowing created pools to stabilize for one year before planting improved their performance. As indicated in Table 4.2 above, year 1 (1993-94) was a dry one, and the hydration of pools was over a shorter period than in year 2 (1994-95), a fact that must be considered in evaluating the results.

Table 4.8 shows that the Vac1 and Vac2 pools one and two years after inoculation yielded essentially similar numbers of aquatic invertebrate taxa. Vac1 did have fewer taxa in its first year than did Vac2, but two years after inoculation, the numbers were essentially the same for the two treatments.

Table 4.8. Numbers of invertebrate taxa in Vac1 and Vac2 pools.

Pool and (treatment)	Taxa in years following innoculation: One year later	Two years later	Three years later
A1 (Vac1)	12	13	13
A2 (Vac2)	10	13	
B4 (Vac1)	10	14	18
B2 (Vac2)	15	16	
C3 (Vac1)	12	15	13
C2 (Vac2)	15	15	

A second way of evaluating the year 1 vs. year 2 inoculations is to examine the actual densities of the taxa under the different treatments. Appendix D presents annual averages of organisms per m of net pull for all taxa in all pools for years 1- 3. In Table 4.9, we have extracted data just for the Vac1 and Vac2 treatments through two years and for the source and control pools in year 1. These data show a reasonably close correspondence between the Vac1 and Vac2 treatments in their first year. For example, in system A these two Vac pools shared nine taxa, and the density values of each were on the same order of magnitude. The same can be said for systems B (9 shared taxa) and C (10 shared). The number of shared species between Vac1 and Vac2 increased in all systems two years after inoculation (9 to 11 in system A, 9 to 13 in system B, and 10 to 13 in system C).

Data on both number of taxa and on taxonomic affinities indicate that the effect of inoculation year is minimal. This conclusion is evident despite the differences in rainfall during this portion of the study. The practical use of this information is that there is no need to wait a second year for inoculating pools, although in some instances it may be desirable to allow the pools to go through one season to evaluate their hydrological performance.

Table 4.9. Annual average number of invertebrates per m of net tow for Vac1 and Vac2 treatments through two years. Data for sources and controls in year 1 are given for comparison. Abbreviations: "Src" for source pools, "Con" for control pools.

SYSTEM	A	A	A	A	A	A	B	B	B	B	B	B
POOL	TR5	A3	A1	A2	A1	A2	TR17	B3	B4	B2	B4	B2
TREATMENT	Src	Con	Vac1	Vac2	Vac1	Vac2	Src	Con	Vac1	Vac2	Vac1	Vac2
YEAR	1	1	1	2	2	3	1	1	1	2	2	3
YRS SINCE INNOC.	na	na	1	1	2	2	na	na	1	1	2	2
flatworm	31			0.12	0.07	1.07	0.25			0.57	0.15	0.23
nematode					0.01	0.02						0.02
gastropod	0.02									0.01		
aphanoneurid worm	0.08											
oligochaete					0.01							
tardigrade					0.07							
calanoid copepod	4	2.72	337	147	157	99		0.03		0.04	0.06	0.64
cyclopoid copepod	514	27	1.61	0.48	0.71	1.38	4.36	80	10	32	17	34
harpacticoid copepod	35										0.01	
chydorid cladoceran			0.03	0.51	0.16	1.42			0.18	40	121	6.91
daphniid cladoceran	4.37		18	8.17	25	2.8	4.24		13	2.78	13	0.36
macrothricid cladoceran					0.05	0.21				0.3	7.77	0.17
moinid cladoceran			0.02				0.86	0.42	177	11	14	3.07
conchostracan									0.08			
ostracod	210		2.7	1.04	2.02	0.41	2724	0.06	56	23	24	1.56
chironomid dipteran			0.58	0.36	0.62	0.98	2.03	0.52	0.65	2.53	0.4	0.81
culicid dipteran			0.03				0.42					
tabanid dipteran										0.01		
collembolan		0.38	0.23	0.46	0.31	0.01		0.37	0.92	1.57	2.46	0.27
corixid hemipteran			0.08	0.06		0.12		0.06	0.53	0.02	0.11	0.04
notonectid hemipteran			0.06			0.04		0.11				0.1
dytiscid beetle	1.14		0.11	0.02	0.05	0.02	0.35		0.67	0.02	0.05	0.01
hydrophilid beetle	0.08						0.06					
oribatid mite										0.01		0.01
water mite	10							0.03			0.01	0.03
TOTAL	811	30	360	158	187	107	2737	81	259	113	199	48
# TAXA	11	3	12	10	13	13	9	9	10	15	14	16

Table 4.9, continued.

SYSTEM	C	C	C	C	C	C
POOL	TR1-4	C1	C3	C2	C3	C2
TREATMENT	Src	Con	Vac1	Vac2	Vac1	Vac2
YEAR	1	1	1	2	2	3
YRS SINCE INNOC.	na	na	1	1	2	2
flatworm	20		0.25	0.18	0.18	0.17
nematode						
gastropod						
aphanoneurid worm	3.56			0.01	0.01	
oligochaete						
tardigrade						
calanoid copepod	0.06		0.03	0.33	0.33	0.01
cyclopoid copepod	475	199	18	19	19	22
harpacticoid copepod	31					
chydorid cladoceran	0.17			0.32	0.32	7.07
daphniid cladoceran	11		0.35	0.02	0.02	
macrothricid cladoceran				3.04	3.04	0.26
moinid cladoceran	1.32	264	229	102	102	1.93
conchostracan						
ostracod	787	0.11	10	12	11.8	5.43
chironomid dipteran	1.44	0.4	0.6	0.88	0.88	1.74
culicid dipteran						
tabanid dipteran						0.01
collembolan	5.52	1.38	0.18	1.27	1.27	0.14
corixid hemipteran	0.13		0.14	0.06	0.06	0.04
notonectid hemipteran		0.02	0.06			0.05
dytiscid beetle	1.7	0.03	0.1	0.01	0.01	0.01
hydrophilid beetle			0.05			
oribatid mite				0.07	0.07	0.02
water mite	1.21			0.02	0.02	0.06
TOTAL	1339	466	259	139	139	39
# TAXA	14	7	12	15	15	15

Effect of transplanting method on the success of aquatic invertebrates. In this section the success of different inoculation methods on invertebrates is compared: the vacuum-scrape method (Vac2 treatment, Vac1 is not included because it was performed a year earlier than other treatments); transplantation of blocks of soil (Blocks treatment); and moving loose soil from source pools to created pools (Soil treatment). All inoculations were performed late in the summer of 1994 after the first winter, and data were taken for two years on each pool. Data show in Appendix D as year 2 and 3, but for these three treatments this is one and two years following inoculation.

One means of evaluating treatments is to see if the number of invertebrate taxa differed significantly among them. The number of taxa was highest in Soil among inoculation treatments in both years (Fig. 4.4), but the effect of treatment was not quite significant (p=.0508). When only the 1996 values for the three inoculation methods were tested as a set, treatment was significant (p=.0452) due to the notably higher values in Soil. Vac2 ranked second, and Blocks was least effective. All treatments had values exceeding the controls (p=.0027), which nonetheless had a number of taxa, with values increasing in year 2. "Year" as a factor was also significant in this data set (p=.0314).

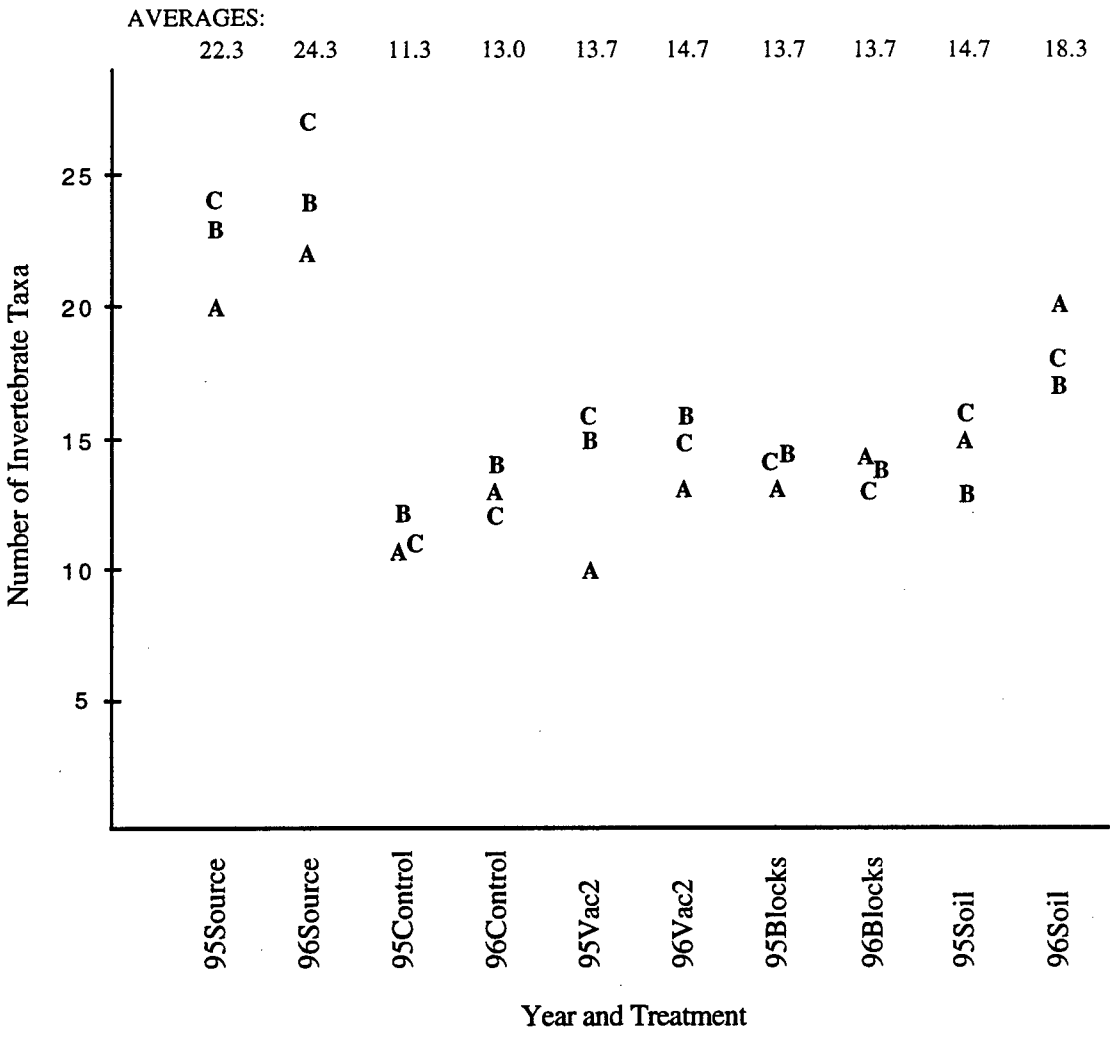

Figure 4.4. Number of the invertebrate taxa listed in Appendix D found in pools in years 2 (one year after inoculation for created pools) and 3 (two years after inoculation). On the x-axis, categories are the three sets of pools in sources, controls and the three treatments for data in year 2 ("95") and 3 ("96"). The letters used to plot values represent the three systems of created pools and their respective sources.

Fig. 4.4 also shows that the source pools had higher numbers of taxa than all created pools in the respective years, and the effect was significant ($p \leq .0001$). Two major factors contributed to this. First, as shown in Tables 4.4 and 4.5 above, several benthic taxa did not do well in created pools. Second, rare taxa were more likely to be found in the somewhat larger source pool samples. In this set of data, "year" also had a significant effect ($p = .0325$), which is largely due to increases in Soil and source samples.

Taxon by taxon differences between source pool fauna and those of treatments are shown graphically in Figs. 4.5-4.7. For simplicity, we averaged data for all treatments (Vac2, Blocks, and Soil), thus no individual inoculated pool has all of the taxa shown in the figures. A log scale was chosen for the y-axis so that widely divergent values could all be portrayed. These figures show graphically how each taxon did with respect to sources. For example, the greater abundance of calanoid copepods and moinid cladocerans in most years is evident, as is the lack of success of aphanoneurid worms, oligochaetes and gastropods in inoculated pools.

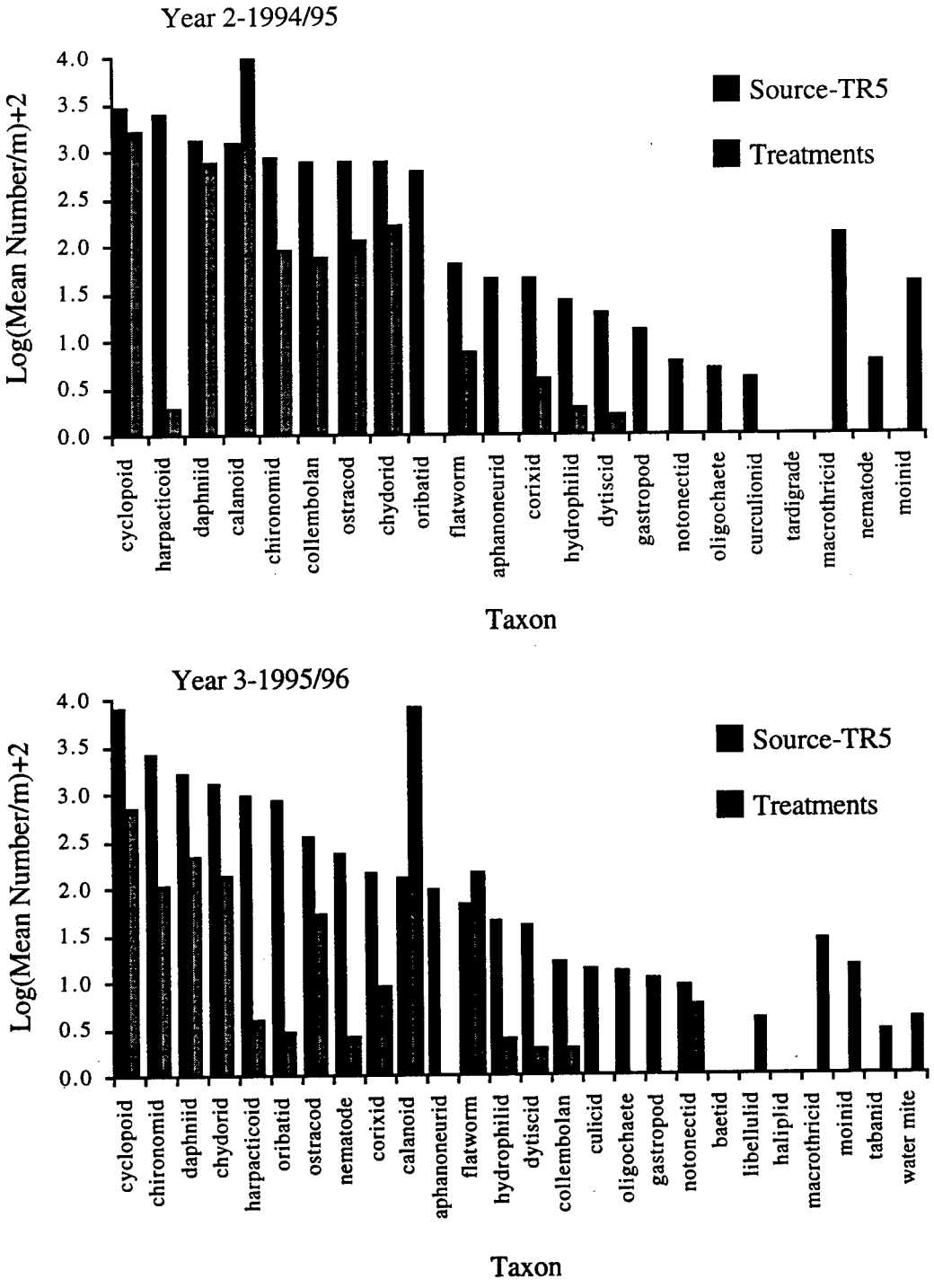

Figure 4.5. Annual average numbers in each taxon for system A through the first two years after inoculation. For taxa with no bars, there was a very small value that did not register graphically.

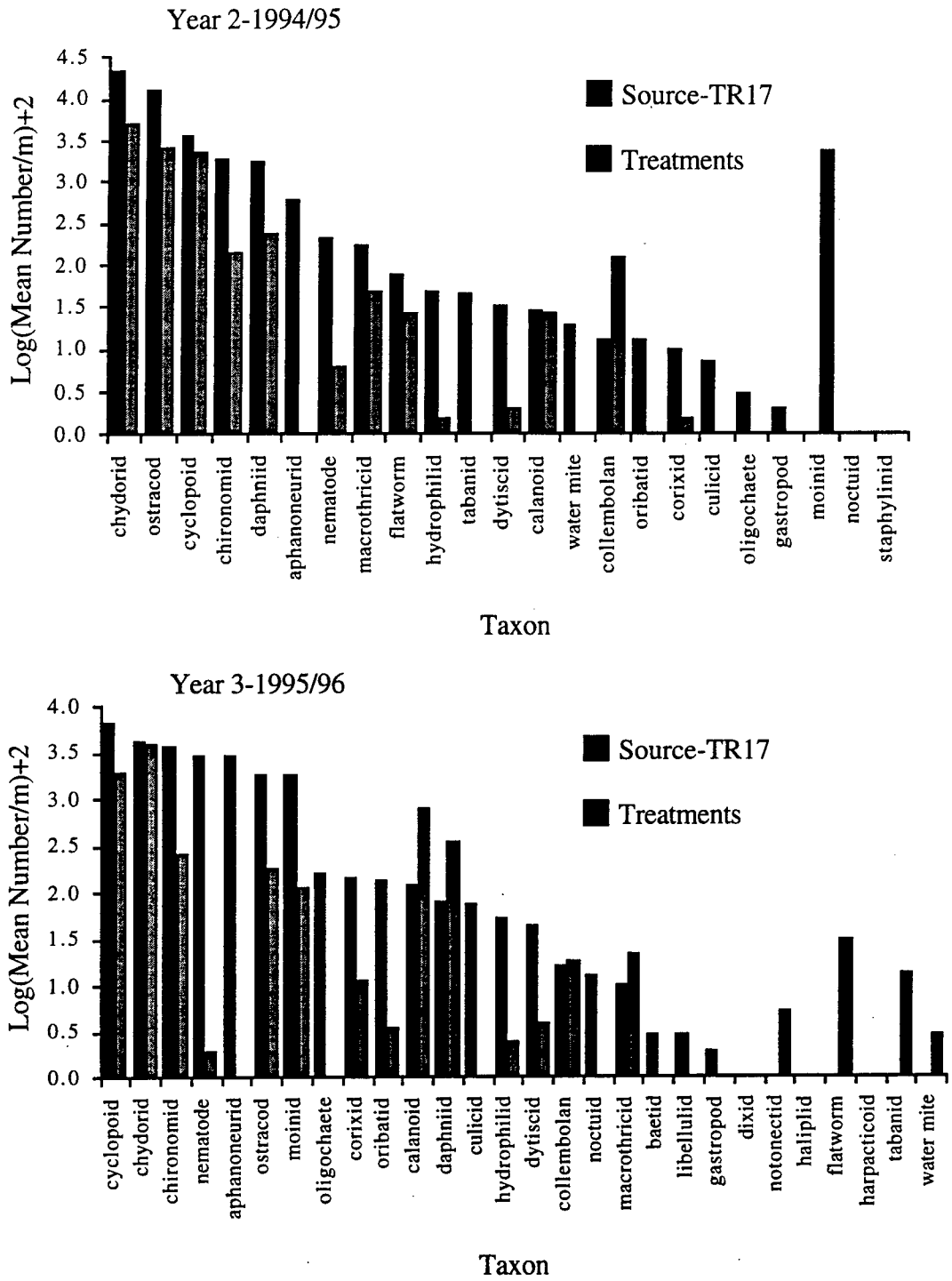

Figure 4.6. Annual average numbers in each taxon for system B through the first two years after inoculation. For taxa with no bars, there was a very small value that did not register graphically.

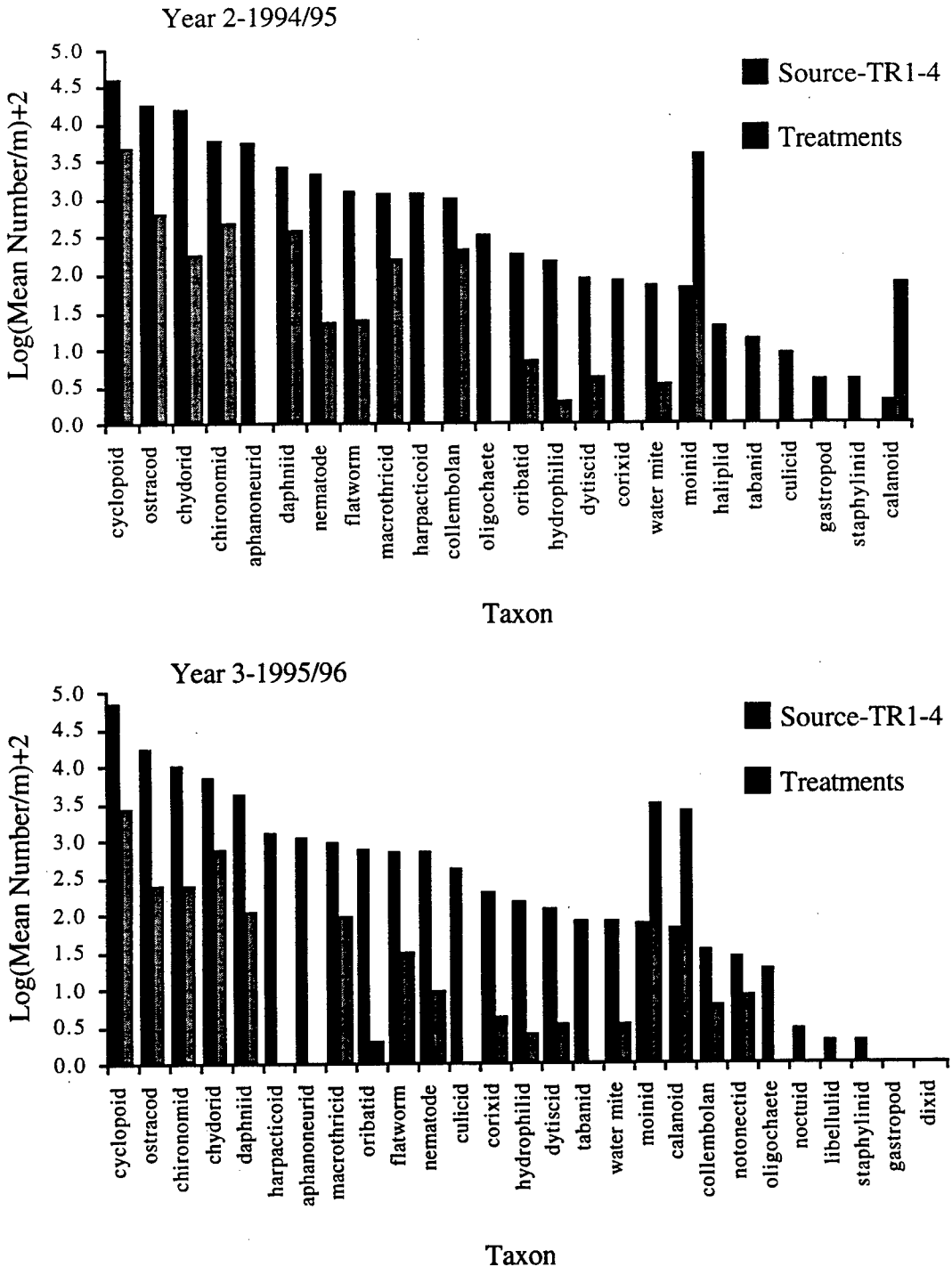

Figure 4.7. Annual average numbers in each taxon for system C through the first two years after inoculation. For taxa with no bars, there was a very small value that did not register graphically.

A second method for determining the success of inoculation treatments is with the index of similarity. How closely does the percentage composition of invertebrate animals in treatment pools, based on annual averages of organisms per meter of net tow, match that of controls and sources in the same year? Using this index, for which 0 represents no correspondence and 100 represents complete similarity, high similarity to sources represents high success, while high similarity to controls represents low success. (Invasion of a treatment pool in a similar manner to controls may represent success in the long term, with both environments collecting local species that disperse into them. In comparison with source pools over the short term, however, the more similar a pool is to controls the less effectively has it responded to inoculation.)

Fig. 4.8 shows similarity indices. In year 1, similarities to sources were much higher in Soil (avg. 67%) than in Blocks (28%), with Vac2 falling in between (49%). By year 2, Vac2 and Soil rated approximately equally (48% vs. 47%), and Blocks had fallen to 23%. Consistency of the values was higher in year 2 in Soil than in Vac2, in which the similarity in system A was low. For similarity to controls, Soil rated best in both years (low values). There was a tendency in most systems for similarity to move closer to controls and farther from sources in the second year, which suggests that the created pools are "using" the source materials along with propagules from other sources to develop their own identities.

Statistically, analysis of variance showed significant effects of treatment for similarity to sources and controls (Table 4.10). Together, the evaluations mean that the soil treatment was superior to the other two. There was also a significant effect of "system" in both indices, which shows in Fig. 4.8 as pools in system A having consistently highest similarity to controls and lowest to sources, with system B generally having the opposite ranking.

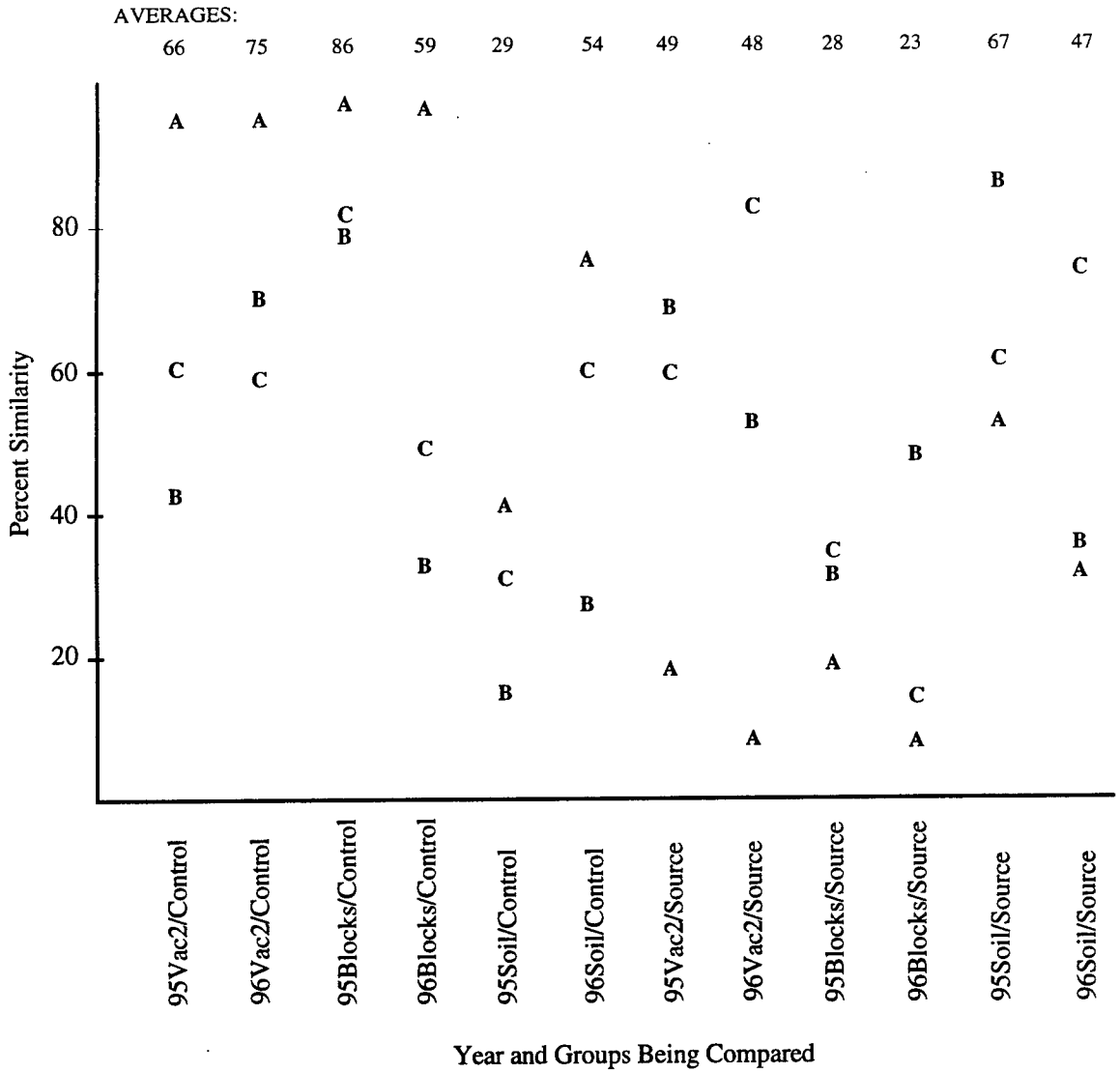

Figure 4.8. Indices of similarity for treatment pools to controls (left half of figure) and sources (right half), based on annual average numbers of organisms per m of net tow shown in Appendix D. The letters used to plot values represent the three systems of created pools and their respective sources.

Table 4.10. Probability values from a multi-way anova on the factors "treatment," "year," and "system" for similarities to Controls and Sources in years 2 and 3.

	Probability values for indices compared to:	
Factor	Sources	Controls
Treatment	0.0214	0.0131
System	0.0099	0.0057
Year	0.3078	0.7571

Physical Conditions in the Pools. As shown in Fig. 4.9, there were differences between source pools and created pools (controls and treatments) in year 2. pH was mildly alkaline in all pools, but slightly less so in the source pools. Temperature was generally higher in source pools, probably because the deep end of the created pools made them heat up more slowly. Some of the small systematic differences among pools, such as the higher temperatures and pH values for created pools in system A, are probably due to the time of day in which data were taken. Turbidity was lower (higher values, since percent transmittance is the unit) in all sources and pools than in the Blocks treatment. It may be that the creation of shallow excavations in which the source blocks were placed created more disruption of these pools than other methods, although the addition of loose soil in the Soil method would seem to have been an even greater disturbance.

Probably the most important difference between source and created pools is the notably higher values for total dissolved solids in the source pools. Measurements were approximately double for the source pools. This phenomenon is likely due to the accumulation of salts in the soil of pools through successive years of hydrating and drying as additional dissolved materials wash into the pools from their surroundings each year.

In year 3, differences between source and created pools in pH and turbidity were slight (Fig. 4.10). The cooler temperatures in created pools seen in year 2 were also found. Total dissolved solids had increased slightly in some created pools, but remained well below values for the source pools (Table 4.11). Values for source pools were also higher in year 3 than 2, however, so increases in any pool may simply reflect different climatic and hydrological conditions in the two years.

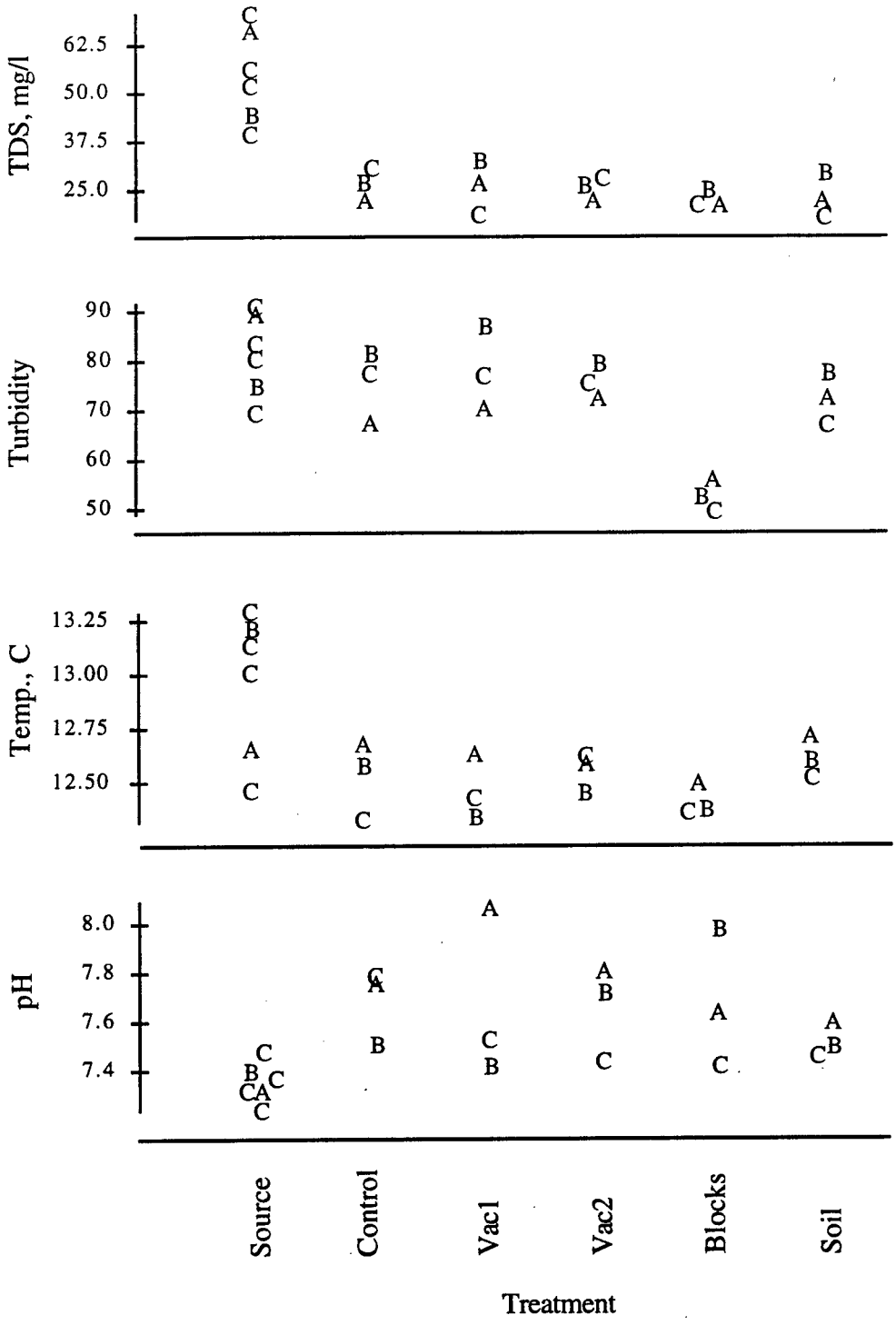

Figure 4.9. Average annual values for pH, temperature, turbidity (% transmittance) and total dissolved solids (TDS) in pools for year 2. The letters used to plot values represent the three systems of created pools and their respective sources.

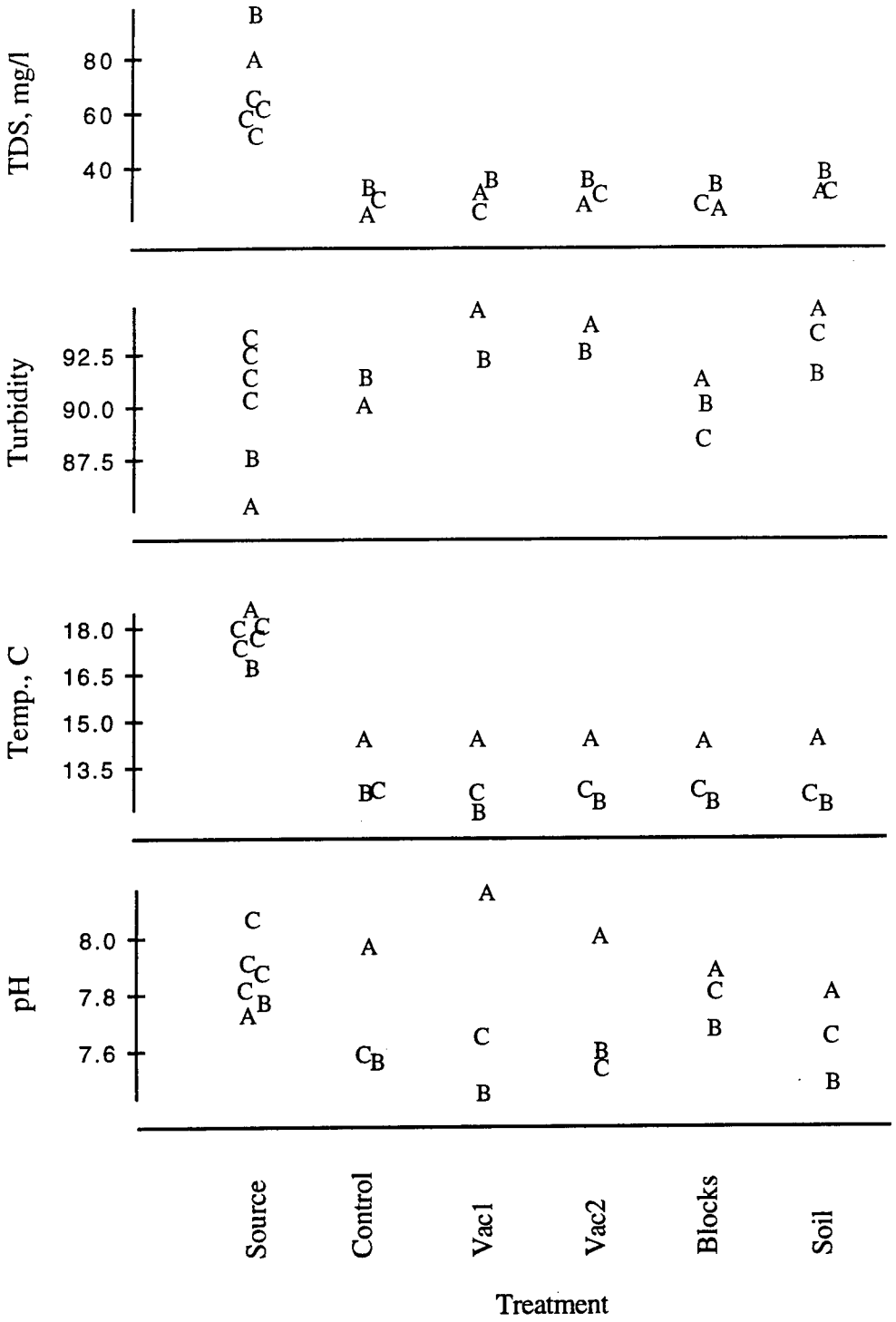

Figure 4.10. Average annual values for pH, temperature, turbidity (% transmittance) and total dissolved solids (TDS) in pools for year 3. The letters used to plot values represent the three systems of created pools and their respective sources.

Table 4.11. Average values for total dissolved solids in mg/l in pool types over two years: year 2 (1994-95) and year 3 (1995-96).

Pool Type	Year 2	Year 3
Source	54.8	68.2
Control	27.3	26.4
Vac1	25.9	27.9
Vac2	26.8	28.1
Blocks	20.1	26.2
Soil	23.2	30.3

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Appendix A-

Supporting Information on

the Setting of the Experiment

TABLE A1-PLANTS OCCURRING IN THE WETLAND DELINEATION OF THE VERNAL POOL CREATION SITE

This table lists plant species that were present in plots of the delineation. The number of upland and wetland points in which each species occurred is shown. Classification of these points into the two categories involved use of information on soils and hydrology as well as plants, based on the 1987 U.S. Army Corps of Engineers Wetland Delineation Manual

Scientific Name	Common Name	Native?	Wetland Type	Points Occurring In	
				Upland	Wetland
Achyrachaena mollis	blow-wives	yes	FAC	1	
Amsinckia menziesii var. intermedia	fiddleneck	yes	UPL	1	
AveSpe	wild oat	no	UPL	24	
Brassica nigra	black mustard	no	UPL	21	
Briza minor	little quaking grass	no	FACW-	6	
Bromus diandrus	ripgut grass	no	UPL	21	
Bromus hordeaceus	soft chess	no	FACU	46	6
Callitriche sp.	water starwort	yes	OBL		1
Carduus pycnocephalus	Italian thistle	no	UPL	1	
Centaurea calcitrapa	purple star-thistle	no	UPL	1	
Centaurea solstitialis	yellow star-thistle	no	UPL	37	2
Convolvulus arvensis	field bindweed	no	UPL	34	7
Crassula sp.	pigmy weed	possibly	FAC		1
Downingia concolor	maroon-spot downingia	yes	OBL		2
Eremocarpus setigerus	dove weed	yes	UPL	17	4
Erodium botrys	broad-leaf filaree	no	UPL	24	2
Eryngium aristulatum var. aristulatum	California coyote thistle	yes	OBL		2
Hemizonia pungens	common spikeweed	yes	FAC	1	3
Hordeum marinum ssp. gussoneanum	Mediterranean barley	no	FAC	2	3
Hypochaeris glabra	smooth cat's-ear	no	UPL	2	1
Juncus bufonius	toad rush	yes	OBL	13	11
Lactuca saligna	willow-leaf lettuce	no	UPL	7	1
Lactuca serriola	prickly lettuce	no	FAC	41	8
Lolium multiflorum	Italian ryegrass	no	FAC	41	9
Lythrum hyssopifolium	loosestrife	no	FACW	5	7
Madia spp.	tarweed	possibly	UPL		1
Medicago polymorpha	California burclover	no	UPL	1	
Picris echioides	bristly ox-tongue	no	FAC*	2	1
Plagiobothrys spp.	popcorn flower	yes	OBL		1
Psilocarphus brevissimus var. multiflorus	Delta woolly marbles	yes	OBL		1
Rumex acetosella	sheep sorrel	no	NI	4	
Rumex crispus	curly dock	no	FACW	5	2
Rumex pulcher	fiddle dock	no	FAC+	2	
Silene gallica	common catchfly	no	UPL	7	1
Sonchus asper ssp. asper	prickly sow thistle	no	FAC	2	1
Taeniatherum caput-medusiae	medusa head	no	UPL	46	8
Vicia sativa	spring vetch	no	FACU	12	1
Vicia sp.	vetch	possibly	UPL	2	
Vulpia bromoides	six-weeks brome	no	FACW	20	3

TABLE A2-MONTHLY PRECIPITATION ON TRAVIS AIR FORCE BASE DURING THE STUDY

Year	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Total
1990-91	0.00	0.00	0.19	0.31	0.00	1.50	0.30	3.60	6.89	0.19	0.24	0.18	13.40
1991-92	0.00	0.70	0.00	1.48	0.38	1.63	1.86	6.56	3.64	0.64	0.00	0.41	17.30
1992-93	0.00	0.00	0.00	1.60	0.21	7.39	9.36	5.32	2.35	0.53	0.81	1.09	28.66
1993-94	0.00	0.00	0.00	0.35	3.02	2.17	1.95	3.38	0.16	1.13	1.03	0.00	13.19
1994-95	0.00	0.00	0.05	0.64	5.23	3.86	12.46	0.16	9.22	1.08	0.71	0.86	34.27
1995-96	0.00	0.00	0.00	0.07	0.00	9.10	7.02	8.52	2.26	2.26	2.62	0.00	31.85

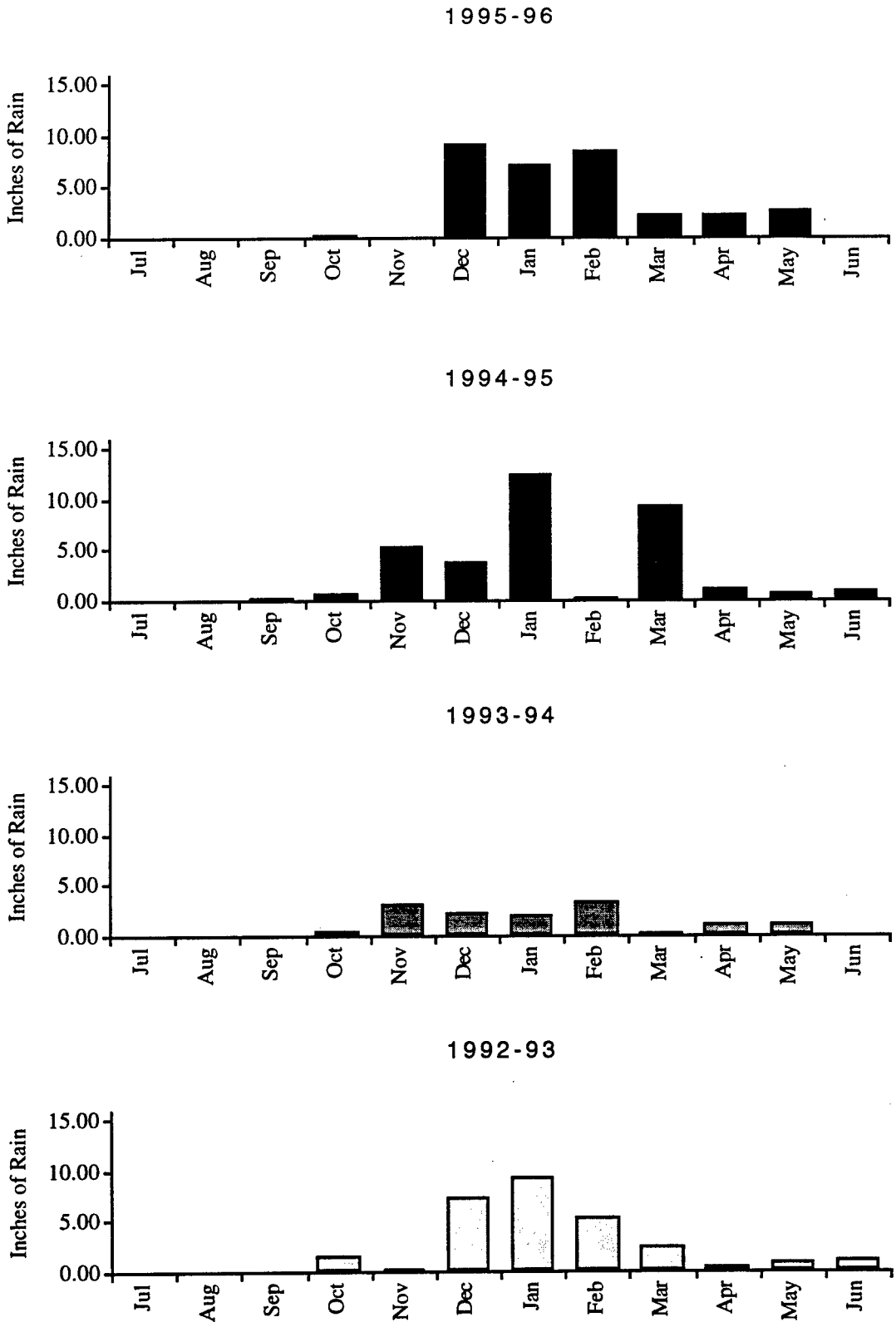


TABLE A1-GRAPHS OF MONTHLY PRECIPITATION ON TRAVIS AIR FORCE BASE DURING THE STUDY

Appendix B-

Supporting Data on Success of Plants

in Created Pools

TABLE B1-PLANT SPECIES OCCURRING IN SAMPLES

Plant species are listed by family, and alphabetically by scientific name within families. Wetland codes are from Reed (1988) and range up in affinity for wetlands from UPL=upland species (generally these species are not listed in Reed, meaning that they are not wetland plants); NI=not included, considered an upland form; FACU=facultative upland species ; FAC=facultative species; FACW=facultative wetland species; and OBL=obligate wetland species. Minus and plus signs are gradations within a category, while an asterisk indicates some disagreement among participants in Reed's inventory of wetland species. All plants from FAC- up are considered to be wetland species. "Sources" are the natural pool systems as shown in Fig. 1 of the text; "Outside" means that the species appeared in a created pool but was not in source pool samples. "Max. Rel. Cover" is the maximum relative cover value for any source system in one of the sampling years 1993-96.

Family	Scientific Name	Common Name	Native	Wetland Type	Sources	Max Rel. Cover
Marsaliaceae	*Pilularia americana*	American pillwort	yes	OBL	B C	6.92
Apiaceae	*Eryngium aristulatum var. aristulatum*	California coyote thistle	yes	OBL	A B	22.09
Asteraceae	*Achyrachaena mollis*	blow-wives	yes	FAC	A C	0.29
	Centaurea calcitrapa	purple star-thistle	no	UPL	A B C	6.36
	Centaurea solstitialis	yellow star-thistle	no	UPL	A C	3.12
	Cotula coronopifolia	brass buttons	no	FACW+	A B C	15.15
	Filago gallica	narrow-leaved filago	no	UPL	C	0.11
	Hemizonia parryi	Parry's tarweed	yes	FAC	C	5.6
	Hemizonia pungens	common spikeweed	yes	FAC	A B Outside	4.48
	Hypochaeris glabra	smooth cat's-ear	no	UPL	C A	1.5
	Hypochaeris radicata	rough cat's ear	no	UPL	Outside	0
	Lactuca serriola	prickly lettuce	no	FAC	C	0.01
	Lasthenia conjugens	Contra Costa goldfields	yes	FACW	B	0.16
	Lasthenia glaberrima	smooth goldfields	yes	OBL	B A C	30.75
	Madia spp.	tarweed	possibly	UPL	Outside	0

Table B1, continued

Family	Scientific Name	Common Name	Native	Wetland Type	Sources	Max Rel. Cover
Asteraceae	*Picris echioides*	bristly ox-tongue	no	FAC*	B	5.22
	Psilocarphus brevissimus var. multiflorus	Delta woolly marbles	yes	OBL	B Outside	1.06
	Xanthium strumarium	cocklebur	yes	FAC+	A	2.71
Boraginaceae	*Plagiobothrys greenei*	popcorn flower	yes	FACW	B C	0.22
	Plagiobothrys stipitatus var. micranthus	popcorn flower	yes	OBL	B C Outside	24.32
	Plagiobothrys trachycarpus	popcorn flower	yes	FACW*	A C B	32.65
Brassicaceae	*Brassica nigra*	black mustard	no	UPL	Outside	0
	Brassica rapa	field mustard	no	UPL	B	0.01
	Lepidium nitidum	pepperwort	yes	UPL	B	0.13
	Raphanus sativus	wild radish	no	UPL	B C Outside	0.04
Callitrichaceae	*Callitriche marginata*	water starwort	yes	OBL	A B C	2.14
Campanulaceae	*Downingia concolor*	maroon-spot downingia	yes	OBL	A B C	21.9
	Downingia insignis	parti-color downingia	yes	OBL	B	0.04
	Downingia pulchella	downingia	yes	OBL	B	0.01
Caryophyllaceae	*Cerastium glomeratum*	mouse-ear chickweed	no	UPL	A	0.01
	Silene gallica	common catchfly	no	UPL	C Outside	0.09
	Spergula arvensis ssp. arvensis	stickwort	no	UPL	C	1.7
	Stellaria nitens	shining chickweed	yes	UPL	C	0.03
Convolvulaceae	*Convolvulus arvensis*	field bindweed	no	UPL	A B C Outside	2.26
Crassulaceae	*Crassula aquatica*	pigmy weed	yes	OBL	A B C Outside	6.61
	Crassula connata	sand pygmy weed	yes	FAC	Outside	0
Cuscutaceae	*Cuscuta howelliana*	Boggs Lake dodder	yes	UPL	A	1.28
Euphorbiaceae	*Eremocarpus setigerus*	dove weed	yes	UPL	A C B	7.84
Fabaceae	*Lotus corniculatus*	birdfoot trefoil	no	FAC	C	0.01
	Lupinus bicolor	miniature lupine	yes	UPL	A C	0.09
	Medicago polymorpha	California burclover	no	UPL	BC	1.9
	Trifolium depauperatum var. truncatum	dwarf sack clover	yes	FAC-	B C	0.15
	Trifolium dubium	little hop clover, shamrock	no	FACU*	A Outside	0.39
	Trifolium fucatum	sour clover	no	FAC	B	0.06

Table B1, continued

Family	Scientific Name	Common Name	Native	Wetland Type	Sources	Max Rel. Cover
Fabaceae	*Trifolium hirtum*	rose clover	no	UPL	Outside	0
	Trifolium oliganthum	few-flowered clover	yes	UPL	B	0.09
	Trifolium sp.	clover	possibly	UPL	C	0.72
	Trifolium willdenovii	tomcat clover	yes	UPL	B	0.59
	Vicia benghalensis	purple vetch	no	UPL	Outside	0
	Vicia sativa	spring vetch	no	FACU	A C	0.51
	Vicia villosa ssp. varia	winter vetch	no	UPL	C Outside	0.13
Gentianaceae	*Cicendia quadrangularis*	foursquare	yes	UPL	Outside	0
Geraniaceae	*Erodium botrys*	broad-leaf filaree	no	UPL	C B A	7.68
	Geranium dissectum	cutleaf geranium	no	UPL	A B	0.46
Lythraceae	*Lythrum californicum*	California loosestrife	yes	OBL	C	0.02
	Lythrum hyssopifolium	loosestrife	no	FACW	C B A Outside	6.16
Onagraceae	*Epilobium brachycarpum*	parched fireweed	yes	UPL	C Outside	0.05
	Epilobium densiflorum	dense-flower spike primrose	yes	OBL	C Outside	0.02
Plantaginaceae	*Plantago elongata*	slender plantain	yes	FACW*	B	0.01
	Plantago lanceolata	English plantain	no	FAC-	B C	0.93
Polemoniaceae	*Navarretia intertexta ssp. intertexta*	needle-leaf navarretia	yes	OBL	C	1.17
	Navarretia squarrosa	skunkweed	yes	UPL	Outside	0
Polygonaceae	*Polygonum arenastrum*	common knotweed	no	FAC	A B C	3.47
	Rumex acetosella	sheep sorrel	no	NI	C Outside	0.47
	Rumex crispus	curly dock	no	FACW	A B Outside	7.74
	Rumex pulcher	fiddle dock	no	FAC+	B	0.17
Portulacaceae	*Calandrinia ciliata*	red maids	yes	FACU*	C Outside	0.14
Primulaceae	*Anagallis arvensis*	scarlet pimpernel	no	FAC	A C	0.01
	Centunculus minimus	chaffweed	yes	OBL	C	0.07
Ranunculaceae	*Ranunculus muricatus*	Prickleseed buttercup	no	FACW	B	0.71
	Ranunculus pusillus	buttercup	yes	FACW	B	0.07
Scrophulariaceae	*Bellardia trixago*	bellardia	no	UPL	C	0.01
	Castilleja attenuata	valley tassels	yes	UPL	Outside	0
	Mimulus guttatus	seep-spring monkey flower	yes	OBL	C	0.01

Table B1, continued

Family	Scientific Name	Common Name	Native	Wetland Type	Sources	Max Rel. Cover
Scrophulariaceae	*Triphysaria eriantha var. eriantha*	butter and eggs	yes	UPL	C	0.82
	Triphysaria versicolor ssp. faucibarbata	butter and eggs	yes	UPL	Outside	0
	Veronica peregrina ssp. xalapensis	purslane speedwell	yes	OBL	A B C Outside	0.39
	Veronica persica	Persian speedwell	no	UPL	Outside	0
Cyperaceae	*Carex aquatilis*	water sedge	yes	OBL	C	0.05
	Carex sp.	sedge	possibly	FACW	Outside	0
	Cyperus eragrostis	umbrella plant	yes	FACW	C	0.01
	Eleocharis macrostachya	spikerush	yes	OBL	A	13.76
Juncaceae	*Juncus bufonius*	toad rush	yes	OBL	C B A	10.17
Juncaginaceae	*Lilaea scilloides*	flowering quillwort	yes	OBL	B C Outside	8.07
Liliaceae	*Brodiaea elegans*	harvest brodiaea	yes	FACU	C	0.07
	Triteleia hyacinthina	white brodiaea	yes	FACW*	A C	0.05
Poaceae	*Agrostis elliottiana*	bent grass	yes	FACW	A	0.09
	Alopecurus saccatus	Pacific foxtail	yes	OBL	B C	3.71
	Avena barbata	slender wild oat	no	UPL	C	0.01
	Avena fatua	wild oat	no	UPL	C	0.01
	Avena sativa	cultivated oat	no	UPL	C	1.06
	Briza minor	little quaking grass	no	FACW-	C	1.65
	Bromus hordeaceus	soft chess	no	FACU	A B C	0.37
	Deschampsia danthonioides	annual hairgrass	yes	FACW	B C	11.63
	Distichlis spicata	saltgrass	yes	FACW	C	0.03
	Hordeum marinum ssp. gussoneanum	Mediterranean barley	no	FAC	A B C	18.4
	Lolium multiflorum	Italian ryegrass	no	FAC	C A B	10.91
	Pleuropogon californicus	semaphore grass	yes	OBL	C B Outside	30.48
	Poa annua	annual bluegrass	no	FACW	B C	1.03
	Poa pratensis	Kentucky bluegrass	no	FACU	Outside	0
	Polypogon monspeliensis	rabbitfoot grass	no	FACW*	A B C Outside	19
	Taeniatherum caput-medusiae	medusa head	no	UPL	Outside	0
	Vulpia bromoides	six-weeks brome	no	FACW	A C	1.34
	Vulpia myuros	rat-tail fescue	no	FACU	C Outside	0.28

TABLE B2-FREQUENCY AND COVER OF INDIVIDUAL SPECIES IN SOURCE POOLS

Table B2.1. Frequency (percentage of samples containing item) for plant species and other features in source pools of systems A, B, and C for 1993-96. Samples beyond pool margins not included. Numbers of samples in successive years: A: 32, 62, 62, 61; B: 67, 65, 67, 67; C: 42, 43, 43, 43.

Name	Pool system and year											
	A93	A94	A95	A96	B93	B94	B95	B96	C93	C94	C95	C96
Achyrachaena mollis		1.6		1.6					4.8		16.3	20.9
Agrostis elliottiana			6.5	3.3								
algal mat			22.6	65.6				47.8			7.0	25.6
Alopecurus saccatus					3.0	7.7	7.5	1.5	11.9	27.9	2.3	20.9
Anagallis arvensis		1.6								2.3	2.3	2.3
Avena barbata									2.4			
Avena fatua									2.4	2.3		2.3
Avena sativa										30.2		
bare ground	90.0	14.5		4.9	100.0	24.6	41.8	9.0	90.5	74.4	48.8	51.2
Bellardia trixago										4.7		
Brassica rapa						1.5						
Briza minor									4.8	23.3	14.0	16.3
Brodiaea elegans											4.7	
Bromus hordeaceus		6.5				6.2			2.4	7.0	2.3	11.6
bulb								1.5				
burrow		1.6										
Calandrinia ciliata										9.3	7.0	
Callitriche marginata					47.8	7.7	7.5	6.0				
Callitriche sp.	15.0				47.8	7.7	7.5	6.0	52.4			
Carex aquatilis											2.3	
Centaurea calcitrapa		9.7				7.7			28.6	86.1		
Centunculus minimus											2.3	
Centaurea solstitialis		4.8								30.2	2.3	2.3
Cerastium glomeratum	3.0											
Convolvulus arvensis	3.0	54.8	51.6	42.6	13.4	23.1	1.5	3.0	33.3	51.2	46.5	18.6
Cotula coronopifolia	25.0	35.5	35.5	41.0	23.9	55.4	38.8	37.3	26.2	58.1	67.4	81.4
Crassula aquatica	34.0				16.4	3.1			83.3	2.3	2.3	18.6
Cuscuta howelliana	6.0	3.2	11.3	3.3								
Cyperus eragrostis				1.6								
Deschampsia danthonioides		3.2			14.9	64.6	67.2	19.4	11.9	60.5	48.8	69.8
Distichlis spicata											2.3	
Downingia concolor	93.0	53.2	69.4	42.6	65.7	49.2	61.2	50.8	35.7	32.6	46.5	46.5
Downingia insignis					1.5		1.5					
Downingia pulchella								3.0				
Eleocharis macrostachya	40.0	24.2	30.7	42.6								4.7
Epilobium brachycarpum										2.3		2.3
Epilobium densiflorum												
Eremocarpus setigerus	37.0	90.3	82.3	88.5		4.6			11.9	30.2	53.5	44.2
Erodium botrys	9.0	38.7	1.6	3.3	3.0	29.2		6.0	7.1	67.4	16.3	18.6
Erodium cicutarium								1.5				
Eryngium aristulatum var. aristulatum	68.0	95.2	100.0	93.4			6.0	34.3				
Filago gallica											7.0	
Geranium dissectum	9.0	19.4				13.9						
gopher mound		3.2							2.4			
grass species									2.4			
Hemizonia parryi			1.6								67.4	41.9
Hemizonia pungens		3.2				83.1	6.0	26.9				

Table B2.1, frequency values, continued.

Name	Pool system and year											
	A93	A94	A95	A96	B93	B94	B95	B96	C93	C94	C95	C96
Geranium dissectum	9.0	19.4				13.9						
gopher mound		3.2							2.4			
grass species									2.4			
Hemizonia parryi			1.6								67.4	41.9
Hemizonia pungens		3.2				83.1	6.0	26.9				
Hordeum marinum ssp. gussoneanum	56.0	59.7	3.2	6.6	25.4	61.5	64.2	34.3	31.0	69.8	55.8	39.5
Hypochaeris glabra		3.2							2.4	48.8	14.0	11.6
Juncus bufonius	6.0	17.7	8.1	1.6	50.8	26.2	1.5		73.8	58.1	48.8	32.6
Lactuca serriola										2.3		
Lasthenia conjugens						6.2	6.0					
Lasthenia glaberrima	25.0	46.8	58.1	26.2	23.9	67.7	97.0	76.1	7.1	7.0	2.3	11.6
Lepidium nitidum						7.7						
Lilaea scilloides	3.0			1.6	14.9	4.6	14.9	14.9	57.1			23.3
Lolium multiflorum		61.3	35.5	14.8	9.0	76.9	67.2	29.9	19.1	69.8	55.8	44.2
Lotus corniculatus												2.3
Lupinus bicolor				1.6					2.4	9.3		4.7
Lythrum californicum												2.3
Lythrum hyssopifolium	37.0	72.6	38.7	50.8	76.1	58.5	17.9	50.8	88.1	86.1	67.4	39.5
Medicago polymorpha	3.0	1.6				33.9				25.6	4.7	11.6
Mimulus guttatus									2.4			2.3
moss										9.3	2.3	4.7
Navarretia intertexta ssp. intertexta										9.3	9.3	2.3
Picris echioides					1.5	56.9	22.4	46.3		4.7		
Pilularia americana					31.3		1.5	1.5			4.7	9.3
Plantago elongata						4.6						
Plagiobothrys greenei					3.0	7.7	7.5		7.1	16.3	14.0	
Plantago lanceolata						12.3				2.3		
Plagiobothrys stipitatus var. micranthus		12.9	8.1	8.2	98.5	87.7	71.6	68.7	16.7	32.6	16.3	62.8
Plagiobothrys trachycarpus	87.0	82.3	91.9	72.1	22.4	13.9			78.6	62.8	81.4	30.2
Pleuropogon californicus					3.0	12.3	50.8	71.6	45.2	46.5	48.8	48.8
Poa annua						53.9	7.5			2.3	7.0	7.0
Polygonum arenastrum			32.3	60.7			7.5	28.4			27.9	37.2
Polypogon monspeliensis	3.0	91.9	96.8	82.0	3.0	33.9	68.7	88.1	9.5	20.9	53.5	79.1
Psilocarphus brevissimus var. multiflorus				1.6	14.9	13.9	10.5	16.4		2.3	7.0	11.6
Ranunculus muricatus						30.8	10.5					
Ranunculus pusillus							3.0	1.5				
Raphanus sativus							1.5					2.3
rock	15.0	8.1	4.8	4.9	1.5				2.4	2.3		
Rumex acetosella									2.4	4.7	2.3	
Rumex crispus	25.0	37.1	46.8	90.2	9.0	26.2	37.3	71.6	2.4	2.3		4.7
Rumex pulcher							4.5					
Silene gallica										14.0		
Spergula arvensis ssp. arvensis									2.4	39.5	16.3	
Stellaria nitens										4.7		
thatch	3.0		14.5	54.1				82.1	2.4		20.9	32.6
Trifolium depauperatum var. truncatum						18.5	1.5			2.3		
Trifolium dubium		3.2	1.6	1.6								

Table B2.1, frequency values, continued.

Name	Pool system and year											
	A93	A94	A95	A96	B93	B94	B95	B96	C93	C94	C95	C96
Triphysaria eriantha var. eriantha						3.1			2.4	23.3		11.6
Trifolium fucatum						4.6						
Triteleia hyacinthina		1.6								7.0		
Trifolium oliganthum							7.5					
Trifolium sp.											18.6	
Trifolium willdenovii						52.3	1.5					
unknown plant		24.2			16.4	3.1			7.1	32.6		
Veronica peregrina ssp. xalapensis	21.0	14.5	12.9		11.9	24.6			38.1	14.0	9.3	
Vicia sativa		3.2							2.4		2.3	4.7
Vicia villosa ssp. varia				1.6						9.3	2.3	2.3
Vulpia bromoides		8.1							7.1	32.6	2.3	
Vulpia myuros											7.0	7.0
Xanthium strumarium			51.6	50.8								

Table B2.2. Average cover for plant species and other features in source pools of systems A, B, and C for 1993-96. Samples beyond pool margins not included. Numbers of samples in successive years: A: 32, 62, 62, 61; B: 67, 65, 67, 67; C: 42, 43, 43, 43.

ScientificName	Pool system and year											
	A93	A94	A95	A96	B93	B94	B95	B96	C93	C94	C95	C96
Achyrachaena mollis		0.02		0.03					0.02		0.44	1.8
Agrostis elliottiana			0.22	0.03								
algal mat			1.34	12.9				8.52			1.34	5.26
Alopecurus saccatus					0.26	1.96	0.62	0.02	0.29	6.52	0.05	0.44
Anagallis arvensis		0.01								0.01	0.01	0.01
Avena barbata									0.01			
Avena fatua									0.01	0.02		0.01
Avena sativa										1.87		
bare ground	15.9	0.31		0.64	44.5	0.72	5.62	0.35	29.6	5.4	2.38	4.06
Bellardia trixago										0.02		
Brassica rapa						0.02						
Briza minor									0.02	0.85	0.89	2.67
Brodiaea elegans											0.1	
Bromus hordeaceus		0.74				0.04			0.01	0.02	0.04	0.1
bulb								0.01				
burrow		0.16										
Calandrinia ciliata										0.12	0.21	
Callitriche marginata					0.91	0.1	0.27	0.08				
Callitriche sp.	0.5								2.8			
Carex aquatilis											0.08	
Centaurea calcitrapa		0.24				0.92			0.88	11.2		
Centunculus minimus											0.11	
Centaurea solstitialis		0.89								5.48	0.03	0.16
Cerastium glomeratum	0.01											
Convolvulus arvensis	0.02	3.2	4.46	1.19	0.14	1.08	0.01	0.05	1.07	3.97	2.71	0.81
Cotula coronopifolia	1.12	2.38	4.49	7.54	3.44	3.99	1.54	0.63	1.06	3.74	8.51	24.6
Crassula aquatica	1.21				0.18	0.11			8.64	0.01	0.01	0.16
Cuscuta howelliana	1.5	0.06	1.35	0.04								
Cyperus eragrostis				0.02								

Table B2.2, cover values, continued.

ScientificName	Pool system and year											
	A93	A94	A95	A96	B93	B94	B95	B96	C93	C94	C95	C96
Deschampsia danthonioides		0.01			0.69	14.1	6.4	0.37	0.28	10.5	15	18.9
Distichlis spicata											0.04	
Downingia concolor	25.6	1.32	6.45	2.32	11.9	4.22	3.98	1.2	13.9	2.37	3.73	8.9
Downingia insignis					0.05		0.05					
Downingia pulchella								0.01				
Eleocharis macrostachya	16.1	14.8	21	18.3								
Epilobium brachycarpum												0.08
Epilobium densiflorum										0.01		0.04
Eremocarpus setigerus	1.03	7.32	18.4	5.33		0.27			0.08	0.2	1.55	1.84
Erodium botrys	0.11	1.18	0.01	0.02	0.02	1.05		0.02	0.61	13.5	0.39	0.56
Erodium cicutarium								0				
Eryngium aristulatum var. aristulatum	1.36	17.8	50.3	33.3			0.53	3.68				
Filago gallica											0.16	
Geranium dissectum	0.09	0.91				0.15						
gopher mound									0.06			
gopher mound		0.32										
grass species									0.36			
Hemizonia parryi			0.02								8.4	4.57
Hemizonia pungens		0.12				7.3	0.27	0.55				
Hordeum marinum ssp. gussoneanum	21	21.6	0.16	0.11	5.07	23.2	24.4	5.38	3.11	8.33	8.86	2.35
Hypochaeris glabra		0.14							0.06	2.64	1.33	1.43
Juncus bufonius	0.07	0.32	0.17	0.03	2.04	0.93	0.07		13.3	7.32	7.31	3.67
Lactuca serriola										0.02		
Lasthenia conjugens						0.2	0.21					
Lasthenia glaberrima	3.62	10.5	14.6	1.14	5.15	22.9	40.9	11	0.1	0.02	0.05	1.36
Lepidium nitidum						0.21						
Lilaea scilloides	0.02			0.08	1.17	0.03	1.46	2.38	10.6			4.09
Lolium multiflorum		18.1	8.6	4.18	1.16	4.63	6.05	3.6	1.53	9.47	16.4	15.8
Lotus corniculatus												0.02
Lupinus bicolor				0.02					0.01	0.16		0.16
Lythrum californicum												0.04
Lythrum hyssopifolium	0.72	4.95	3.94	3.27	2.29	10	0.52	2.71	4.17	9.65	7.52	3.7
Medicago polymorpha	0.02	0.01				3.1				1.98	0.09	0.47
Mimulus guttatus									0.01			0.02
moss										2.71	0.08	0.12
Navarretia intertexta ssp. intertexta										0.97	1.75	0.1
Picris echioides					0.02	8.5	1.06	2.57		0.02		
Pilularia americana					7.94		0.02	0.08			0.26	0.78
Plantago elongata						0.02						
Plagiobothrys greenei					0.08	0.08	0.29		0.14	1.01	0.19	
Plantago lanceolata						1.53				0.02		
Plagiobothrys stipitatus var. micranthus		0.23	0.24	0.22	24.3	39.6	10.6	3.02	2.48	10.5	2.02	4.36
Plagiobothrys trachycarpus	24.5	65	41.5	13.7	1.91	0.58			16.9	30	14.4	9.94
Pleuropogon californicus					0.1	0.53	9.52	39.8	14.3	14.1	25.6	13.8
Poa annua						1.68	0.3			0.04	0.14	0.31
Polygonum arenastrum			1	3.45			0.06	1.04			3.18	5.62
Polypogon monspeliensis	0.02	19.5	44.7	19.7	0.07	3.05	14.8	18	0.55	3.12	11.2	14.1
Psilocarphus brevissimus var. multiflorus				0.03	0.52	0.79	0.38	1.38		0.01	0.12	0.29

Table B2.2, cover values, continued.

ScientificName	Pool system and year											
	A93	A94	A95	A96	B93	B94	B95	B96	C93	C94	C95	C96
Ranunculus muricatus						1.16	0.72					
Ranunculus pusillus							0.09	0.04				
Raphanus sativus							0.05					0.01
rock	0.94	0.51	0.4	0.64	0.01				0.04	0.02		
Rumex acetosella									0.08	0.82	0.22	
Rumex crispus	0.94	3.75	6.9	11.7	0.57	2.37	1.66	6.04	0.02	0.06		0.05
Rumex pulcher							0.22					
Silene gallica										0.16		
Spergula arvensis ssp. arvensis									0.06	2.98	0.3	
Stellaria nitens										0.05		
thatch	0.05		0.5	6.49				18.1	0.71		1.4	2.64
Trifolium depauperatum										0.01		
Trifolium depauperatum var. truncatum						0.25	0.01					
Trifolium dubium		0.78	0.22	0.4								
Triphysaria eriantha var. eriantha						0.01			0.02	0.67		1.33
Trifolium fucatum						0.09						
Triteleia hyacinthina		0.01								0.08		
Trifolium oliganthum							0.12					
Trifolium sp.											1.08	
Trifolium willdenovii						0.95	0.01					
unknown plant		0.8			0.12	0.06			0.13	1.31		
Veronica peregrina ssp. xalapensis	0.46	0.58	0.16		0.05	0.46			0.45	0.08	0.04	
Vicia sativa		0.05							0.67		0.02	0.11
Vicia villosa				0.01								0.1
Vicia villosa ssp. varia										0.23	0.1	
Vulpia bromoides		0.48							1.75	1.48	0.12	
Vulpia myuros											0.09	0.46
Xanthium strumarium			3.9	4.09								
Total cover	117	199	235	151	115	163	133	131	131	176	150	162

TABLE B3-PLANT SPECIES AND RELATIVE COVER VALUES OF THE THREE POOL SYSTEMS

Each table below gives the relative cover value for species, expressed as the percent cover relative to all items. Because the non-living items, like bare ground, are not in the table, the total relative cover for a given sample does not always equal 100%. The source pool samples include all samples from the source pools, not just the 10 samples used for statistical analysis. Wetland types are from Reed (1988). Species are ranked in decreasing order of cover values in the source pools in 1995, then alphabetically.

Table B3.1. Species and cover values in Pool System A.

Scientific Name	Native	Wetland Type	Source Pools				Controls			Vac 1			Vac 2		Blocks		Soil	
			93	94	95	96	94	95	96	94	95	96	95	96	95	96	95	96
Eryngium aristulatum var. aristulatum	yes	OBL	1.16	8.93	21.40	22.09		0.07			9.71	15.18	2.75	14.99	3.27	13.81	2.79	16.51
Polypogon monspeliensis	no	FACW*	0.02	9.81	19.00	13.02		0.13	0.03	0.09	0.62	0.03	9.82	0.36	7.72	9.31	10.07	11.36
Plagiobothrys trachycarpus	yes	FACW*		32.65	17.68	9.07		0.20	0.46		15.35	1.48	33.11	9.87	12.43	10.92	24.31	20.88
Eleocharis macrostachya	yes	OBL	13.76	7.43	8.92	12.14						0.11		0.28		0.02		1.57
Eremocarpus setigerus	yes	UPL	0.88	3.68	7.84	3.53				2.41	2.85	0.44	7.94	1.75	2.60	1.27	1.37	1.44
Lasthenia glaberrima	yes	OBL	3.10	5.29	6.22	0.76				6.68	11.98	9.08	9.28	13.09	10.00	6.27	22.63	15.76
Lolium multiflorum	no	FAC		9.07	3.66	2.77	0.27		0.29	3.46	0.11		1.25	0.08	7.38	8.19	2.83	2.81
Rumex crispus	no	FACW	0.80	1.88	2.94	7.74			0.03				0.11	0.23	0.08			0.02
Downingia concolor	yes	OBL	21.90	0.66	2.75	1.54		0.20	1.08	4.85	21.10	13.93	14.74	31.33	24.13	14.72	17.87	2.72
Cotula coronopifolia	no	FACW+	0.96	1.20	1.91	4.99				0.15	0.33	0.36	0.07	0.13	1.99	6.68	1.02	0.26
Convolvulus arvensis	no	UPL	0.02	1.61	1.90	0.79	1.87	9.75	9.51	0.12	0.81	0.03	5.59	3.14				
Lythrum hyssopifolium	no	FACW	0.62	2.49	1.68	2.17		3.87	13.44		0.19	0.53	1.36	0.23	2.92	0.86	1.50	0.14
Xanthium strumarium	yes	FAC+			1.66	2.71					0.67	0.56	1.39	1.19	1.73	0.79	0.92	0.46
Cuscuta howelliana	yes	UPL	1.28	0.03	0.57	0.03					11.52	2.36	0.81	1.27	1.09		0.56	
Polygonum arenastrum	no	FAC			0.43	2.29					0.19	0.08	2.12	1.96	1.30	3.64	1.12	3.10
Plagiobothrys stipitatus var. micranthus	yes	OBL		0.12	0.10	0.15				26.08	0.95	0.23	0.27	0.02	9.69	0.13	5.17	
Agrostis elliottiana	yes	FACW			0.09	0.02												
Trifolium dubium	no	FACU*		0.39	0.09	0.26									1.24	0.99		
Hordeum marinum ssp. gussoneanum	no	FAC	17.97	10.85	0.07	0.07				10.69		0.03	1.09		6.63	11.10	1.63	
Juncus bufonius	yes	OBL	0.06	0.16	0.07	0.02			0.07			0.03	0.43		2.54	0.05	3.20	
Veronica peregrina ssp. xalapensis	yes	OBL	0.39	0.29	0.07							0.23	0.05		0.05		0.06	
Hemizonia parryi	yes	FAC			0.01													0.02
Erodium botrys	no	UPL	0.09	0.59	0.00	0.01		0.20								0.11		
Achyrachaena mollis	yes	FAC		0.01		0.02									0.65	1.10		
Alopecurus saccatus	yes	OBL													0.13	0.79		
Anagallis arvensis	no	FAC		0.01									0.02					
Brassica nigra	no	UPL						0.13	0.03									
Bromus hordeaceus	no	FACU		0.37						0.09								

Table B3.1, continued. Cover values in Pool System A.

Scientific Name	Native	Wetland Type	Source Pools				Controls			Vac 1			Vac 2		Blocks		Soil	
			93	94	95	96	94	95	96	94	95	96	95	96	95	96	95	96
Calandrinia ciliata	yes	FACU*													0.26			
Callitriche sp.	yes	OBL	0.43															
Centaurea calcitrapa	no	UPL		0.12														
Centaurea solstitialis	no	UPL		0.45			0.40											
Cerastium glomeratum	no	UPL	0.01															
Cicendia quadrangularis	yes	UPL													0.10			
Crassula aquatica	yes	OBL	1.04						0.03	0.09	0.17	0.98		0.08	0.13			
Crassula connata	yes	FAC																
Cyperus eragrostis	yes	FACW				0.01										0.21	0.07	0.34
Deschampsia danthonioides	yes	FACW		0.01									0.09		0.05		0.97	0.37
Epilobium brachycarpum	yes	UPL						0.03										0.02
Epilobium densiflorum	yes	OBL															0.01	
Geranium dissectum	no	UPL	0.08	0.46														
Hemizonia pungens	yes	FAC		0.06					0.03				0.61	0.23	0.03		0.03	
Hypochaeris glabra	no	UPL		0.07														
Lilaea scilloides	yes	OBL	0.02			0.05				0.30	1.56	3.32	0.11		0.11	2.65		
Lotus corniculatus	no	FAC																
Lupinus bicolor	yes	UPL				0.01										0.37		
Lythrum californicum	yes	OBL							0.46									
Madia spp.	poss.	UPL							0.03									
Medicago polymorpha	no	UPL	0.02	0.01														
Plantago lanceolata	no	FAC-					0.03											
Plagiobothrys spp.	yes	OBL	20.94															
Pleuropogon californicus	yes	OBL															1.81	20.03
Psilocarphus brevissimus var. multiflorus	yes	OBL				0.02		0.23	7.96			0.50		0.05				
Rumex acetosella	no	NI											0.04					
Triteleia hyacinthina	yes	FACW*		0.01														
Vicia benghalensis	no	UPL							0.17							0.82		
Vicia sativa	no	FACU		0.03														
Vicia villosa ssp. varia	no	UPL				0.01	0.50											
Vulpia bromoides	no	FACW		0.24														
Vulpia myuros	no	FACU														0.50		
TOTAL			85.11	98.41	99.06	86.29	2.67	14.81	33.62	55.01	78.11	49.49	93.05	80.28	97.99	95.30	99.94	97.81

Table B3.2. Species and cover values in Pool System B.

Scientific Name	Native	Wetland Type	Source Pools				Controls			Vac 1			Vac 2		Blocks		Soil	
			93	94	95	96	94	95	96	94	95	96	95	96	95	96	95	96
Lasthenia glaberrima	yes	OBL	4.49	14.02	30.75	8.39				17.38	26.93	22.25	20.80	22.89	14.95	21.95	16.64	25.30
Hordeum marinum ssp. gussoneanum	no	FAC	4.42	14.23	18.40	4.12				18.64	3.51	0.02	3.07	0.05	1.10	2.84	3.04	0.38
Polypogon monspeliensis	no	FACW*	0.06	1.87	11.15	13.80			0.03		1.02	0.62	7.20	1.05	12.25	4.78	4.79	5.17
Plagiobothrys stipitatus var. micranthus	yes	OBL	21.17	24.32	8.00	2.31			0.66	31.18	24.14	9.53	26.36	10.15	24.45	1.31	18.15	0.17
Pleuropogon californicus	yes	OBL	0.09	0.32	7.17	30.48					0.23		8.86	3.01	14.33	35.68	18.09	32.09
Deschampsia danthonioides	yes	FACW	0.60	8.66	4.82	0.28				0.93	0.39	0.33	8.07	0.08	1.82	0.47	5.86	2.57
Lolium multiflorum	no	FAC	1.01	2.84	4.55	2.75	0.17		0.22	0.84	0.12		0.32		0.18	0.39	1.20	1.26
Downingia concolor	yes	OBL	10.37	2.59	3.00	0.92		0.30	0.66	1.38	20.37	10.24	5.79	9.35	15.00	5.25	14.72	3.53
Rumex crispus	no	FACW	0.50	1.45	1.25	4.62			0.66				0.05	0.10	0.05	0.02		0.21
Cotula coronopifolia	no	FACW+	3.00	2.45	1.16	0.48				1.56	1.40	0.36	6.99	4.41	3.77	3.31	1.32	1.58
Lilaea scilloides	yes	OBL	1.02	0.02	1.10	1.82						0.14			0.33	2.95	0.68	2.29
Picris echioides	no	FAC*	0.02	5.22	0.80	1.97				0.58							0.28	0.42
Ranunculus muricatus	no	FACW		0.71	0.54					0.14	0.01				0.53		0.84	
Alopecurus saccatus	yes	OBL	0.23	1.20	0.47	0.02				0.47	0.77	0.09	0.27	0.10	0.05		2.36	
Eryngium aristulatum var. aristulatum	yes	OBL			0.40	2.82					0.23	0.48	0.03			0.34	0.06	2.04
Lythrum hyssopifolium	no	FACW	2.00	6.16	0.39	2.07	0.23	13.90	11.35	1.17	5.50	4.56	0.52	0.23	0.23	0.17	1.78	0.69
Psilocarphus brevissimus var. multiflorus	yes	OBL	0.45	0.49	0.29	1.06		3.08	18.98	1.42	5.25	20.95	0.39	9.54	0.62	4.13	1.06	8.74
Poa annua	no	FACW		1.03	0.23												0.05	
Plagiobothrys greenei	yes	FACW	0.07	0.05	0.22					0.16								
Callitriche marginata	yes	OBL	0.79	0.06	0.20	0.06												
Hemizonia pungens	yes	FAC		4.48	0.20	0.42				0.21	2.21	2.59	0.85	4.64	2.01	0.37	0.96	0.11
Rumex pulcher	no	FAC+			0.17													
Lasthenia conjugens	yes	FACW		0.12	0.16												0.15	0.04
Trifolium oliganthum	yes	UPL			0.09												2.84	0.55
Ranunculus pusillus	yes	FACW			0.07	0.03									0.49			
Juncus bufonius	yes	OBL	1.78	0.57	0.05		0.37	0.32	0.32	14.43	0.43		1.09		0.51	0.06	1.95	
Polygonum arenastrum	no	FAC			0.05	0.80					0.09	0.16				0.15		0.11
Downingia insignis	yes	OBL	0.04		0.04													
Raphanus sativus	no	UPL			0.04													
Pilularia americana	yes	OBL	6.92		0.02	0.06					0.06	6.84		0.67	0.28	2.26	0.18	
Convolvulus arvensis	no	UPL	0.12	0.66	0.01	0.04	0.30	1.05	0.66	2.37	1.78	0.41	0.54	0.48		0.02		
Trifolium depauperatum var. truncatum	yes	FAC-		0.15	0.01					0.07							0.47	
Trifolium willdenovii	yes	UPL		0.59	0.01					0.02								

Table B3.2,continued. Cover values in Pool System B.

Scientific Name	Native	Wetland Type	Source Pools				Controls			Vac 1			Vac 2		Blocks		Soil	
			93	94	95	96	94	95	96	94	95	96	95	96	95	96	95	96
Brassica nigra	no	UPL						0.10					0.01					
Brassica rapa	no	UPL		0.01														
Briza minor	no	FACW-								0.02								
Bromus hordeaceus	no	FACU		0.02														
Calandrinia ciliata	yes	FACU*													0.13			
Centaurea calcitrapa	no	UPL		0.56														
Cicendia quadrangularis	yes	UPL													0.13		0.07	
Crassula aquatica	yes	OBL	0.16	0.06				0.07	0.39		0.03	0.12	0.01	0.08	0.05	0.02	0.01	
Crassula connata	yes	FAC					0.03											
Downingia pulchella	yes	OBL				0.01												
Epilobium brachycarpum	yes	UPL					0.20	2.63					0.03					
Epilobium densiflorum	yes	OBL									0.72		0.66		1.28		0.15	
Eremocarpus setigerus	yes	UPL		0.16			0.07	0.62	0.13		0.20	0.09	0.11	0.44	0.01	0.15	0.02	0.13
Erodium botrys	no	UPL	0.02	0.64		0.02				0.54								
Geranium dissectum	no	UPL		0.09														
Hypochaeris glabra	no	UPL								0.02								
Hypochaeris radicata	no	UPL									0.03							
Lepidium nitidum	yes	UPL		0.13						0.02								
Lythrum californicum	yes	OBL							0.71					1.15		0.52		0.11
Medicago polymorpha	no	UPL		1.90						0.65							0.41	
Navarretia squarrosa	yes	UPL						1.21										
Plantago elongata	yes	FACW*		0.01														
Plantago lanceolata	no	FAC-		0.93						0.04	0.09		0.01					
Plagiobothrys spp.	yes	OBL													0.08			
Plagiobothrys trachycarpus	yes	FACW*	1.67	0.36							0.26		0.30		1.08	2.15	1.03	1.95
Poa pratensis	no	FACU								0.09								
Taeniatherum caput-medusiae	no	UPL														0.02		
Triphysaria eriantha var. eriantha	yes	UPL		0.01														
Trifolium fucatum	no	FAC		0.06														
Veronica persica	no	UPL							0.03					0.02				
Veronica peregrina ssp. xalapensis	yes	OBL	0.04	0.28				0.10			0.05		0.01				0.04	
Vicia benghalensis	no	UPL														0.32		
Vicia villosa ssp. varia	no	UPL							0.03								0.29	
Vulpia myuros	no	FACU																0.42
TOTAL			61.04	99.48	95.81	79.35	1.37	23.38	34.83	94.33	95.82	79.78	92.34	68.44	95.71	89.63	99.49	89.86

Table B3.3. Species and cover values in Pool System C.

Scientific Name	Native	Wetland Type	Source Pools				Controls			Vac 1			Vac 2		Blocks		Soil	
			93	94	95	96	94	95	96	94	95	96	95	96	95	96	95	96
Pleuropogon californicus	yes	OBL	10.90	8.01	17.07	8.52				0.42	8.09	3.75	4.56	4.96	11.81	11.40	10.76	11.25
Lolium multiflorum	no	FAC	1.17	5.39	10.91	9.77	1.70	5.53	1.95	15.62	2.26	0.75	0.64	0.07	3.39	2.46	3.06	4.29
Deschampsia danthonioides	yes	FACW	0.21	5.97	9.99	11.63				0.23	1.07	0.99	3.99	1.97	3.69	3.56	3.24	4.31
Plagiobothrys trachycarpus	yes	FACW*		17.04	9.59	6.13			0.13		8.61	0.02	11.93	0.20	9.61	6.07	11.20	0.15
Polypogon monspeliensis	no	FACW*	0.42	1.77	7.44	8.71			0.71		0.35	1.55	28.04	11.17	2.49	8.09	1.08	6.05
Hordeum marinum ssp. gussoneanum	no	FAC	2.38	4.74	5.91	1.45	0.03			16.08	0.02		0.77	0.05	0.31			
Cotula coronopifolia	no	FACW+	0.81	2.13	5.68	15.15				0.07	2.59	1.03	6.32	3.07	2.20	4.14	0.66	3.11
Hemizonia parryi	yes	FAC			5.60	2.82					3.43	0.88	1.52	0.05	2.34	1.79	2.76	0.88
Lythrum hyssopifolium	no	FACW	3.19	5.49	5.02	2.28	0.03	0.19	12.19	0.26	3.29	2.02	1.09	0.59	5.17	3.56	6.15	4.23
Juncus bufonius	yes	OBL	10.17	4.16	4.87	2.26	0.23	5.47	1.10	0.26	2.61	9.97	2.37	1.69	9.24	5.76	9.42	6.18
Downingia concolor	yes	OBL	10.62	1.35	2.49	5.49	0.03	0.37	1.24	0.26	42.05	22.44	14.10	13.33	13.72	12.65	30.57	20.86
Polygonum arenastrum	no	FAC			2.12	3.47						0.18		0.02	0.02	0.13		0.11
Convolvulus arvensis	no	UPL	0.82	2.26	1.81	0.50	2.73	8.55	1.73	0.72	1.17	1.06	4.69	0.88	0.02	0.60		
Plagiobothrys stipitatus var. micranthus	yes	OBL	1.90	6.00	1.35	2.69			0.49	15.39	7.33	5.91	2.41	10.68	2.89	1.83	6.95	8.65
Navarretia intertexta ssp. intertexta	yes	OBL		0.55	1.17	0.06				0.03	1.19	0.44	0.11		0.02		0.07	0.11
Eremocarpus setigerus	yes	UPL	0.06	0.11	1.03	1.13	0.03	1.31	0.13	0.17	0.40	0.10	0.75	0.24	0.44	0.76	0.11	0.21
Hypochaeris glabra	no	UPL	0.05	1.50	0.89	0.88				0.10	0.05				0.33	0.21	0.12	0.62
Trifolium sp.	poss.	UPL			0.72													
Briza minor	no	FACW-	0.02	0.48	0.59	1.65		0.12	0.03			1.11			0.63	0.65	1.17	1.81
Achyrachaena mollis	yes	FAC	0.02		0.29	1.11				0.03						0.39		0.02
Erodium botrys	no	UPL	0.47	7.68	0.26	0.35				0.81		0.44		0.05	0.58	0.26	0.62	0.15
Spergula arvensis ssp. arvensis	no	UPL	0.05	1.70	0.20					0.20	0.51			0.02	0.23		0.44	
Pilularia americana	yes	OBL			0.17	0.48						4.61	0.21	9.67	9.51	8.07	0.71	8.82
Rumex acetosella	no	NI	0.06	0.47	0.15						0.07							
Calandrinia ciliata	yes	FACU*		0.07	0.14					0.29								
Plagiobothrys greenei	yes	FACW	0.11	0.57	0.13					0.59	0.77	0.33	0.19	0.10	0.31		0.28	0.17
Filago gallica	no	UPL			0.11			0.07			0.42	0.88			0.02	0.02	0.02	0.10
Poa annua	no	FACW		0.02	0.09	0.19									0.04			
Psilocarphus brevissimus var. multiflorus	yes	OBL		0.01	0.08	0.18			0.10		0.05	0.18	0.72	5.33	0.04	0.91		0.11
Vulpia bromoides	no	FACW	1.34	0.84	0.08		0.10	0.16		1.79	0.28						0.14	
Brodiaea elegans	yes	FACU			0.07													
Centunculus minimus	yes	OBL			0.07													
Vicia villosa ssp. varia	no	UPL		0.13	0.07	0.06				0.17								0.54

Table B3.3, continued. Cover values in Pool System C.

Scientific Name	Native	Wetland Type	Source Pools				Controls			Vac 1			Vac 2		Blocks		Soil	
			93	94	95	96	94	95	96	94	95	96	95	96	95	96	95	96
Medicago polymorpha	no	UPL		1.13	0.06	0.29				0.07					0.08	0.11		
Vulpia myuros	no	FACU			0.06	0.28						0.02						0.02
Carex aquatilis	yes	OBL			0.05													
Alopecurus saccatus	yes	OBL	0.22	3.71	0.03	0.27			0.32		0.56	0.23	2.43	0.20	0.11	0.37	0.05	1.67
Bromus hordeaceus	no	FACU	0.01	0.01	0.03	0.06				0.39		0.13						0.02
Distichlis spicata	yes	FACW			0.03													
Lasthenia glaberrima	yes	OBL	0.08	0.01	0.03	0.84			0.03	0.23			0.36	0.76	1.21	2.65	0.11	0.17
Veronica peregrina ssp. xalapensis	yes	OBL	0.34	0.05	0.03								0.15		0.38		0.09	
Centaurea solstitialis	no	UPL		3.12	0.02	0.10				0.39								0.02
Anagallis arvensis	no	FAC		0.01	0.01	0.01					0.02						0.05	0.02
Crassula aquatica	yes	OBL	6.61	0.01	0.01	0.10		0.07	0.52		0.33	2.46	0.21	0.42	1.70		0.05	0.07
Vicia sativa	no	FACU	0.51		0.01	0.07									0.31		0.64	0.71
Agrostis elliottiana	yes	FACW																
Avena barbata	no	UPL	0.01															
Avena fatua	no	UPL	0.01	0.01		0.01									0.08		0.02	
Avena sativa	no	UPL		1.06														
Bellardia trixago	no	UPL		0.01														
Brassica nigra	no	UPL						16.85										
Callitriche marginata	yes	OBL							0.17									
Callitriche sp.	yes	OBL	2.14															
Carex sp.	poss.	FACW							0.88									
Castilleja attenuata	yes	UPL									0.58				0.17	0.95	0.34	0.75
Centaurea calcitrapa	no	UPL	0.67	6.36														
Eleocharis macrostachya	yes	OBL							0.03									
Epilobium brachycarpum	yes	UPL				0.05					0.05					0.05		0.04
Epilobium densiflorum	yes	OBL		0.01		0.02					1.10		0.08					
Hemizonia pungens	yes	FAC								1.60				0.02				
Lactuca serriola	no	FAC		0.01														
Lilaea scilloides	yes	OBL	8.07			2.52				0.03		0.96		0.37	5.67	12.17	6.89	4.25
Lotus corniculatus	no	FAC				0.01												
Lupinus bicolor	yes	UPL	0.01	0.09		0.10				0.03		0.08				0.05		0.28
Lythrum californicum	yes	OBL				0.02						1.61		0.05		1.41		0.22

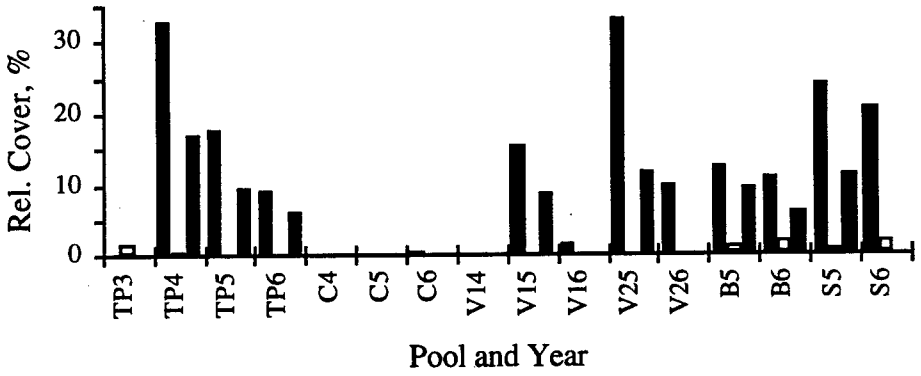
Table B3.3, continued. Cover values in Pool System C.

Scientific Name	Native	Wetland Type	Source Pools				Controls			Vac 1			Vac 2		Blocks		Soil	
			93	94	95	96	94	95	96	94	95	96	95	96	95	96	95	96
Mimulus guttatus	yes	OBL	0.01			0.01						0.05						
Picris echioides	no	FAC*		0.01													0.04	
Plantago lanceolata	no	FAC-		0.01														
Plagiobothrys spp.	yes	OBL	12.95									0.47		0.91				
Raphanus sativus	no	UPL				0.01			0.10									
Rumex crispus	no	FACW	0.02	0.03		0.03			0.85							0.21		
Silene gallica	no	UPL		0.09			0.03	0.07		0.03							0.16	
Stellaria nitens	yes	UPL		0.03														
Taeniatherum caput-medusiae	no	UPL						0.68			0.16		0.15		0.11	0.06		
Trifolium depauperatum var. truncatum	yes	FAC-		0.01						0.20	0.12	0.13			0.14			
Trifolium dubium	no	FACU*													0.11	1.42		
Triphysaria eriantha var. eriantha	yes	UPL	0.02	0.38		0.82						4.10				1.90		1.46
Trifolium hirtum	no	UPL																0.06
Triteleia hyacinthina	yes	FACW*		0.05											0.08			
Triphysaria versicolor ssp. faucibarbata	yes	UPL													0.13		0.04	
Veronica persica	no	UPL										0.05		0.42		0.24		0.10
Vicia benghalensis	no	UPL														0.05		
TOTAL			76.45	94.65	96.53	92.58	4.91	39.44	22.70	56.46	89.53	68.93	87.79	67.29	89.33	94.95	98.01	92.59

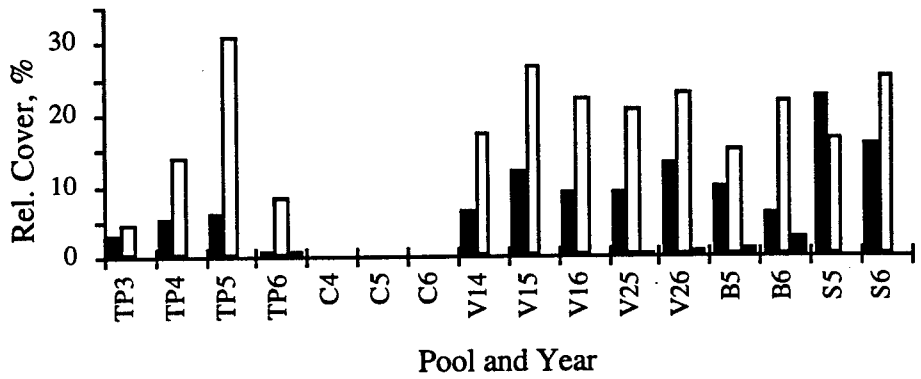
FIGURE B.1-GRAPHS OF RELATIVE COVER FOR EACH SPECIES

For each graph, the relative cover is shown for all source pools, controls, and inoculation treatments over all years. For source pools, all samples were used in the calculation, and these are designated as "TP3" for total pool, 1993, etc. For controls and treatments, a letter or letter and number designate the treatment, and the last number the year. For example, "C4" designates Control 1994, "V14" Vac1 1994, "V24" Vac2 1994, "B5" Blocks 1995, and "S5" Soil 1995. Within each of these pool/year designations, the three pool systems are represented with a black bar for System A, a white bar for B, and a gray bar for C. The species are presented in order of decreasing relative cover in the source pool systems. Species with minimal cover in only one source area and one year are omitted. The scale of the y-axis varies from graph to graph so that the pattern can be seen for species with lower cover.

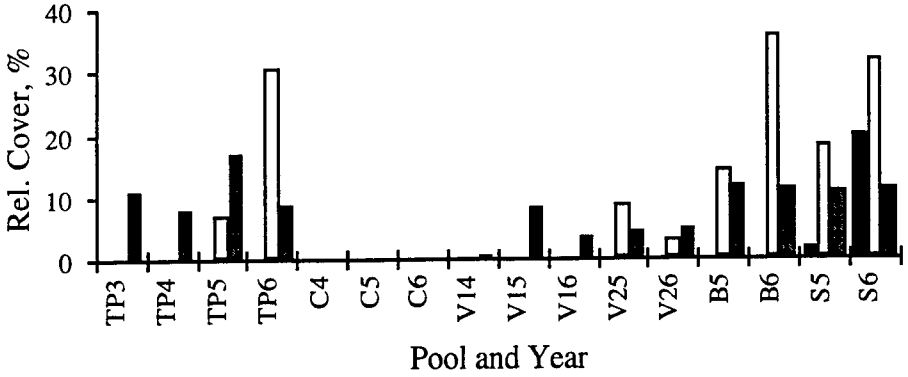
Plagiobothrys trachycarpus



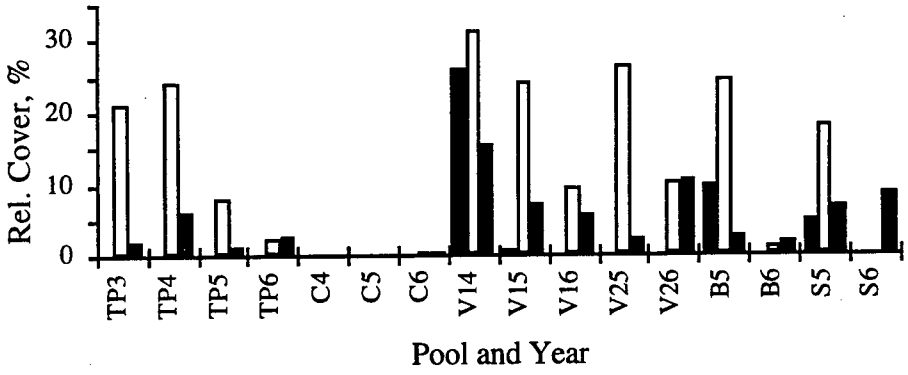
Lasthenia glaberrima



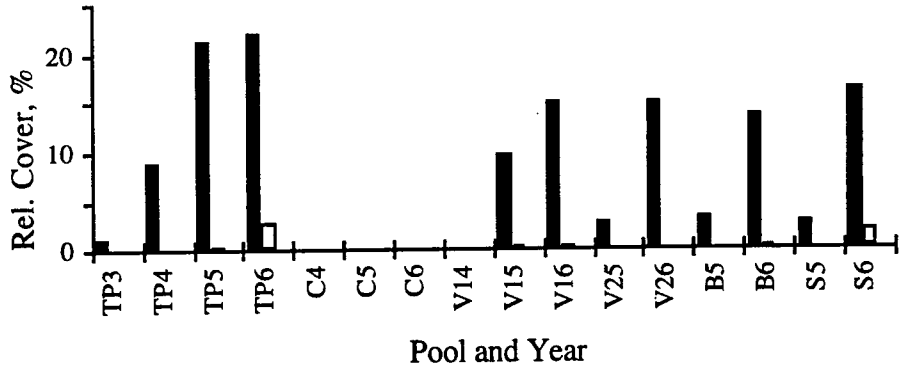
Pleuropogon californicus



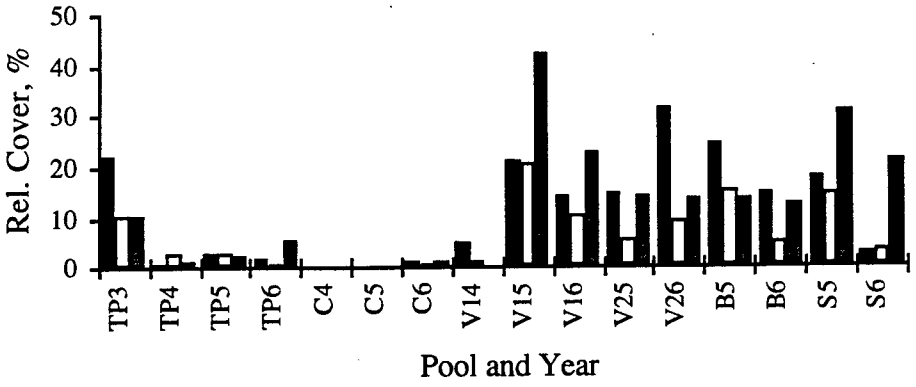
Plagiobothrys stipitatus var. micranthus



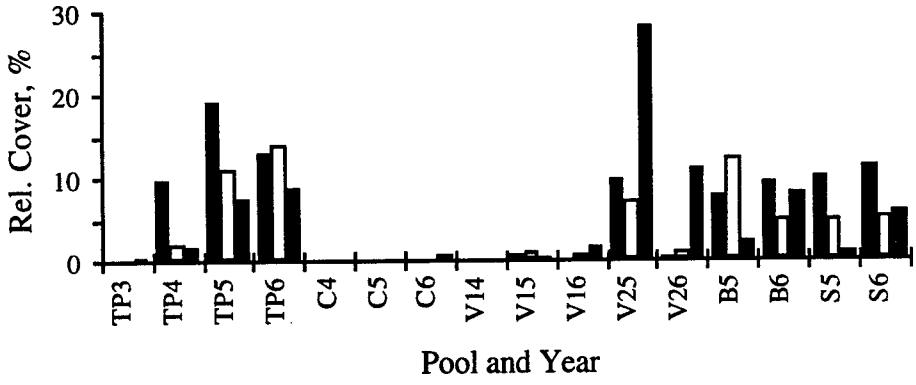
Eryngium aristulatum var. aristulatum



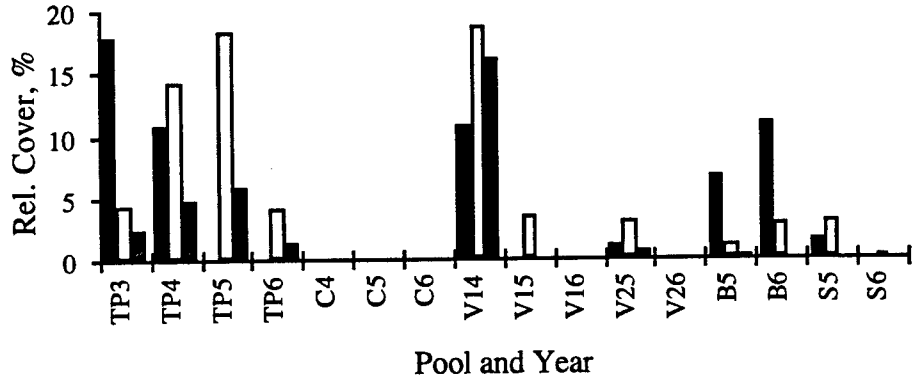
Downingia concolor



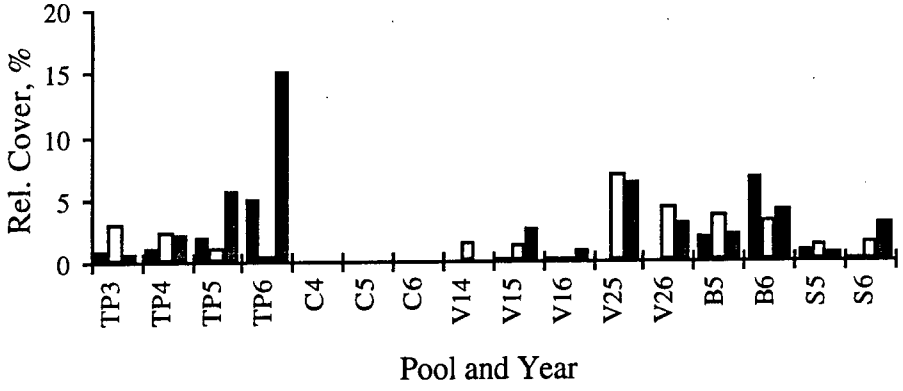
Polypogon monspeliensis



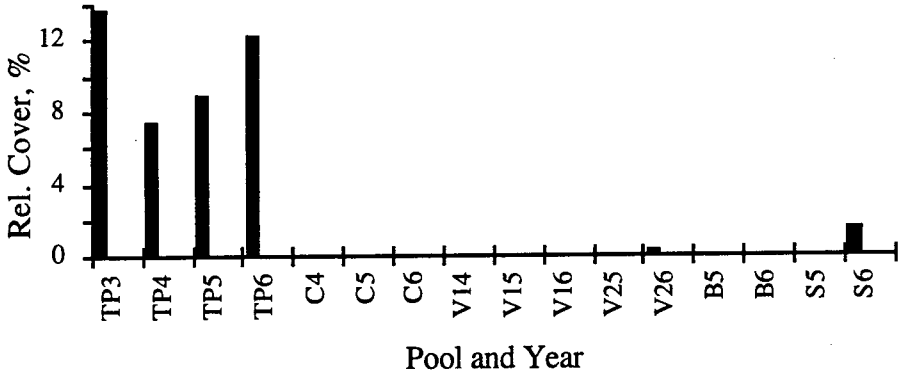
Hordeum marinum ssp. gussoneanum



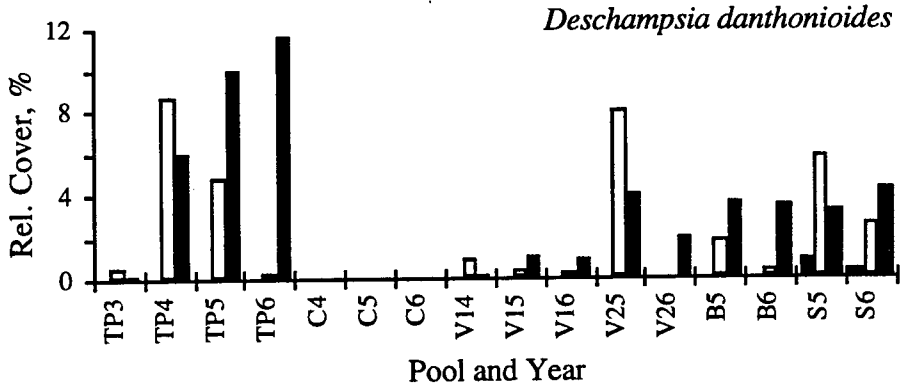
Cotula coronopifolia

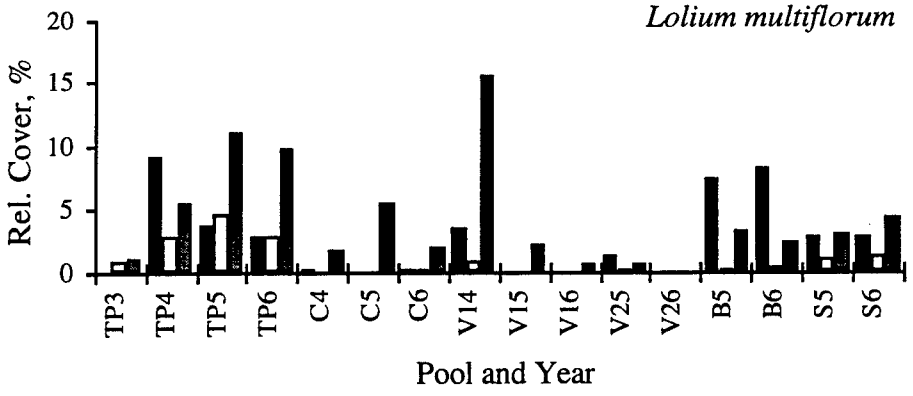


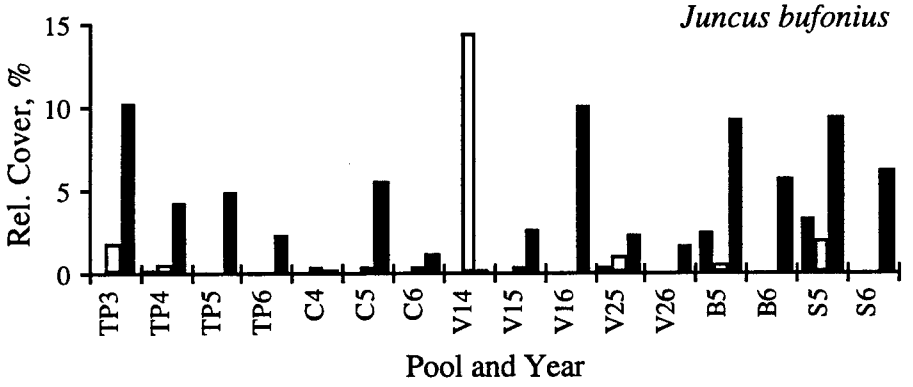
Eleocharis macrostachya

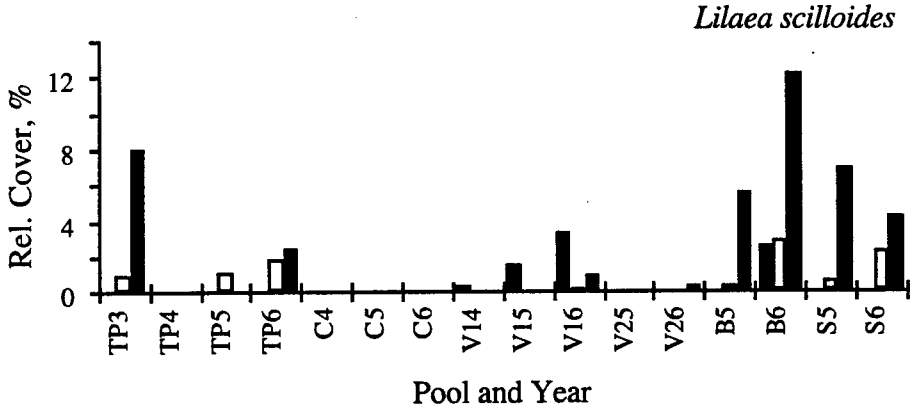


Deschampsia danthonioides

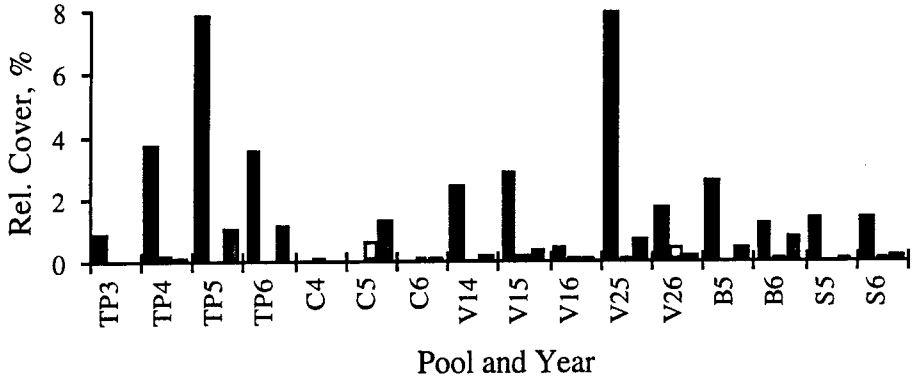



Lolium multiflorum
Rel. Cover, %
20
15
10
5
0
TP3
TP4
TP5
TP6
C4
C5
C6
V14
V15
V16
V25
V26
B5
B6
S5
S6
Pool and Year

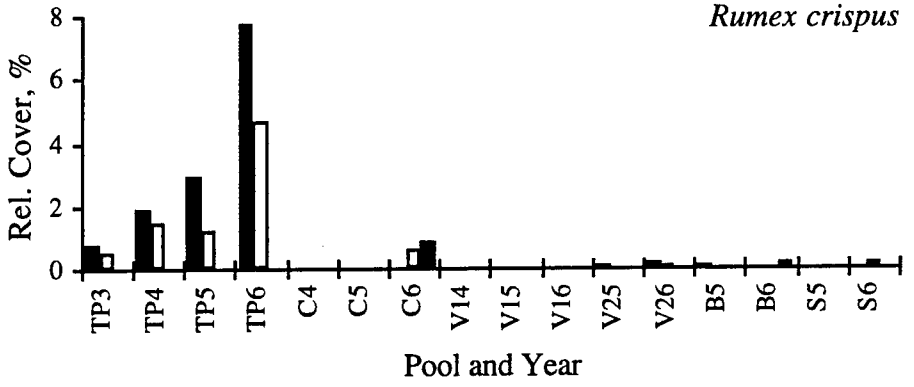

Juncus bufonius
Rel. Cover, %
15
10
5
0
TP3
TP4
TP5
TP6
C4
C5
C6
V14
V15
V16
V25
V26
B5
B6
S5
S6
Pool and Year


Lilaea scilloides
Rel. Cover, %
12
8
4
0
TP3
TP4
TP5
TP6
C4
C5
C6
V14
V15
V16
V25
V26
B5
B6
S5
S6
Pool and Year

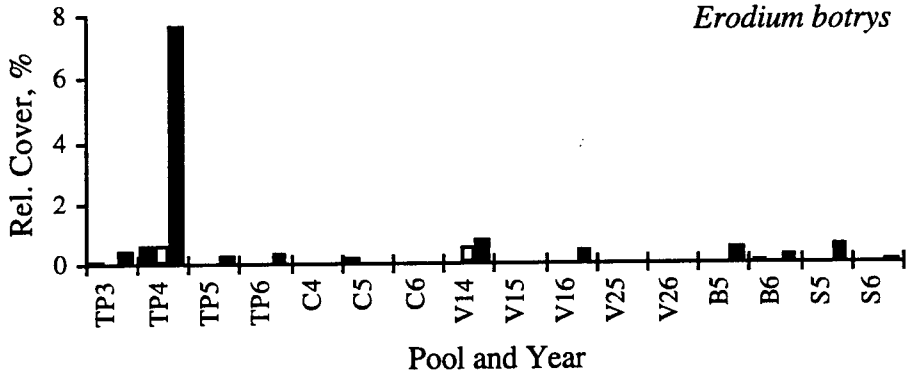
Eremocarpus setigerus

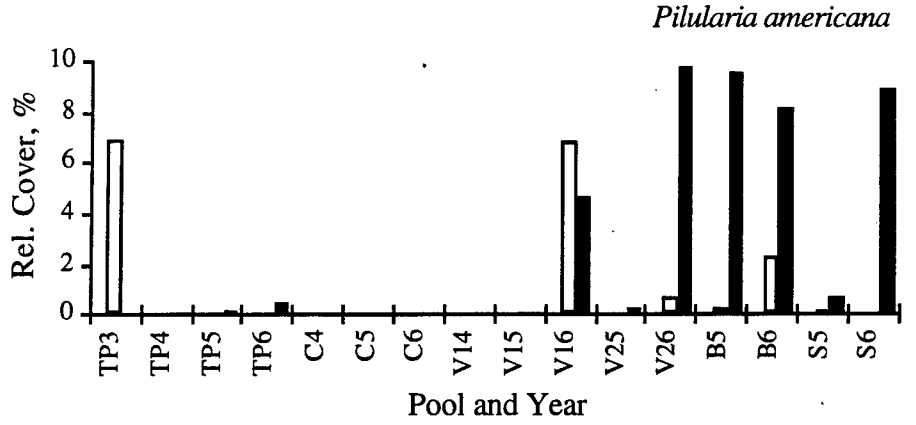


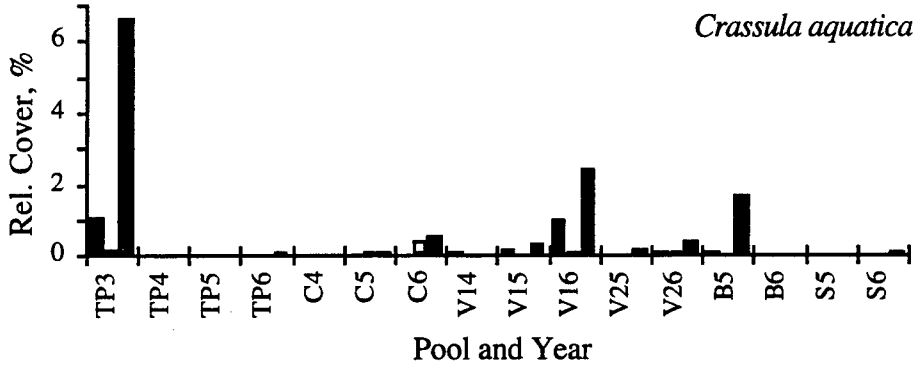
Rumex crispus

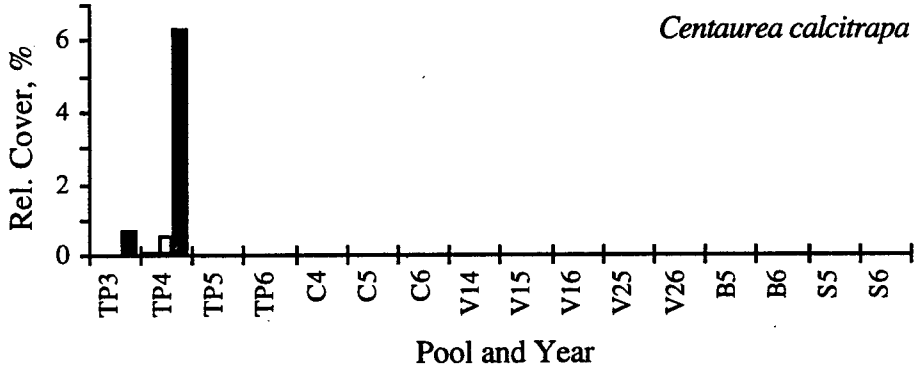


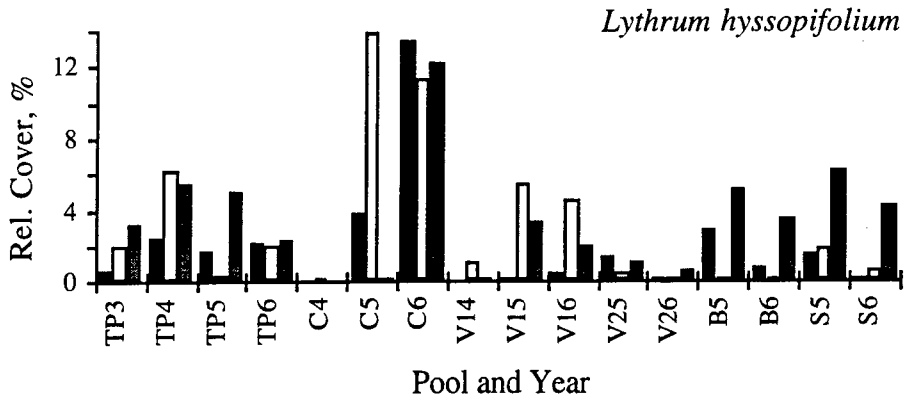
Erodium botrys

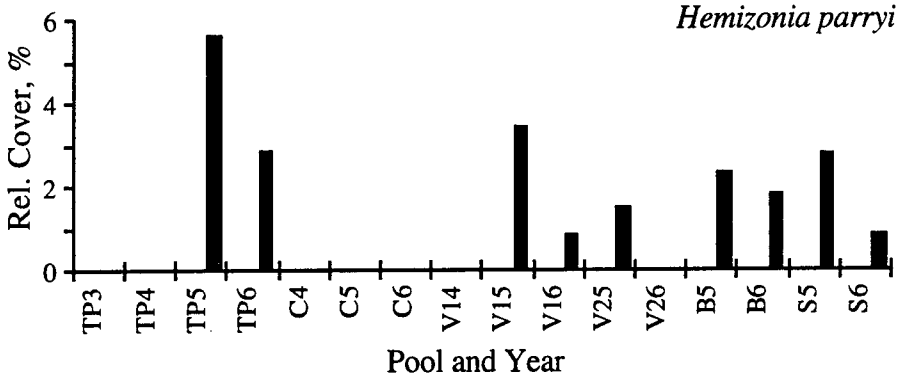


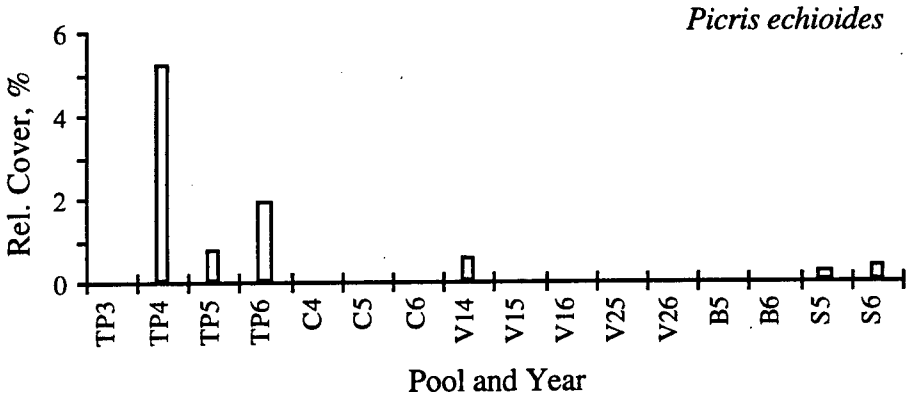

Pilularia americana
Rel. Cover, %
10
8
6
4
2
0
TP3
TP4
TP5
TP6
C4
C5
C6
V14
V15
V16
V25
V26
B5
B6
S5
S6
Pool and Year


Crassula aquatica
Rel. Cover, %
6
4
2
0
TP3
TP4
TP5
TP6
C4
C5
C6
V14
V15
V16
V25
V26
B5
B6
S5
S6
Pool and Year

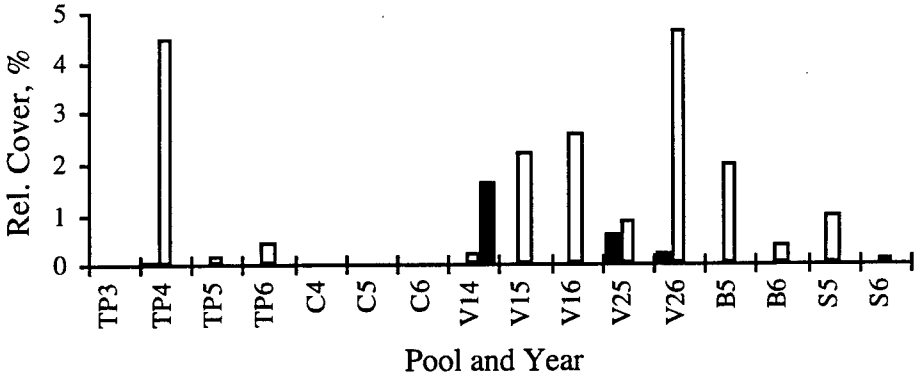

Centaurea calcitrapa
Rel. Cover, %
6
4
2
0
TP3
TP4
TP5
TP6
C4
C5
C6
V14
V15
V16
V25
V26
B5
B6
S5
S6
Pool and Year


Lythrum hyssopifolium
Rel. Cover, %
0
4
8
12
TP3
TP4
TP5
TP6
C4
C5
C6
V14
V15
V16
V25
V26
B5
B6
S5
S6
Pool and Year

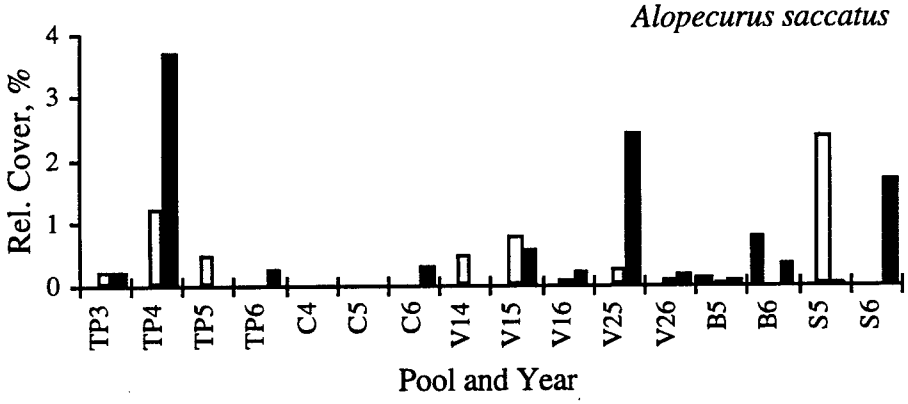

Hemizonia parryi
Rel. Cover, %
0
2
4
6
TP3
TP4
TP5
TP6
C4
C5
C6
V14
V15
V16
V25
V26
B5
B6
S5
S6
Pool and Year


Picris echioides
Rel. Cover, %
0
2
4
6
TP3
TP4
TP5
TP6
C4
C5
C6
V14
V15
V16
V25
V26
B5
B6
S5
S6
Pool and Year

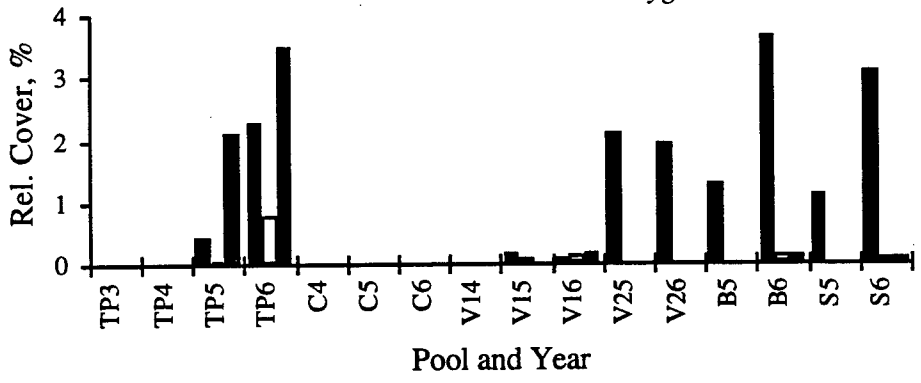
Hemizonia pungens

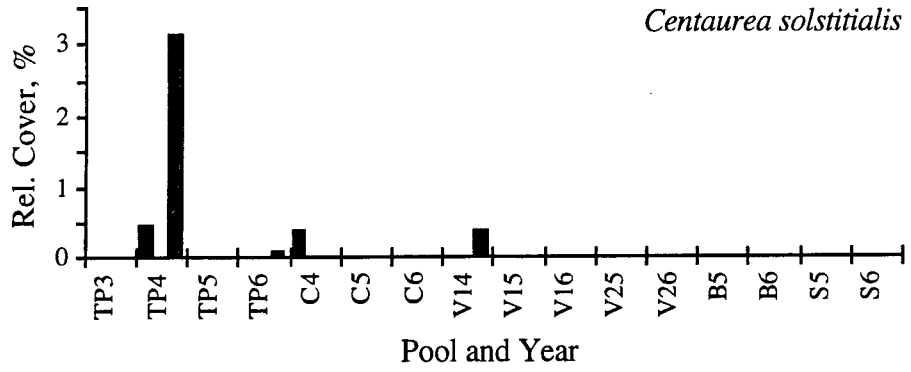


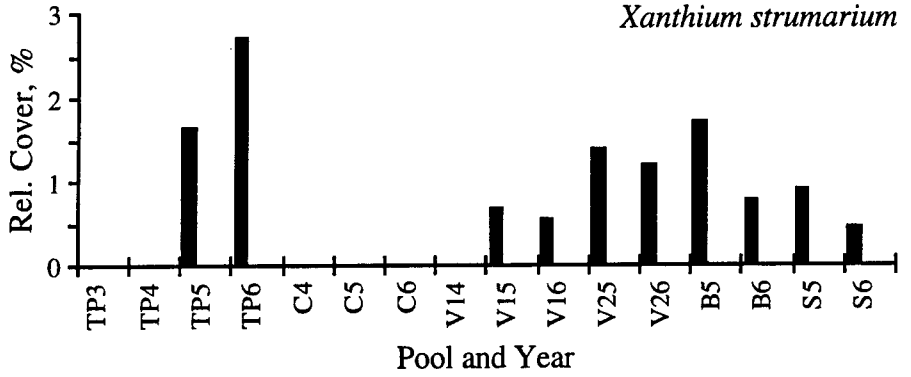
Alopecurus saccatus

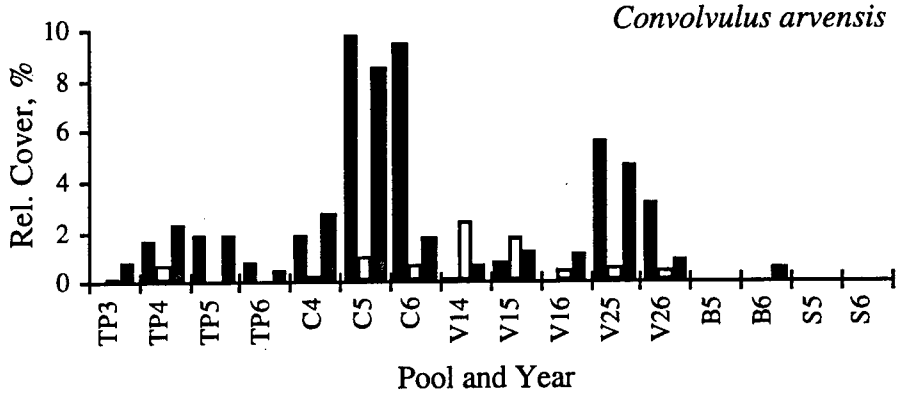


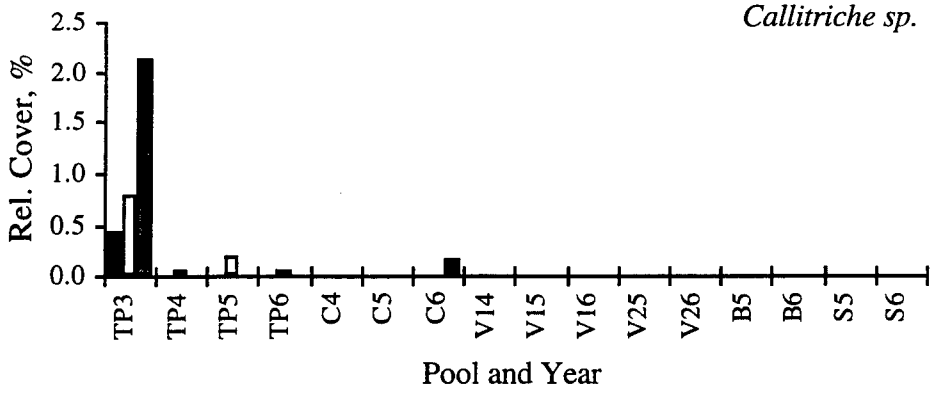
Polygonum arenastrum

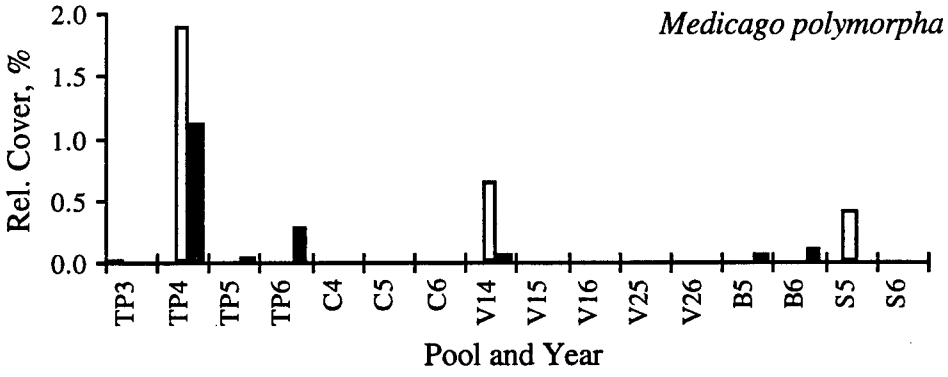


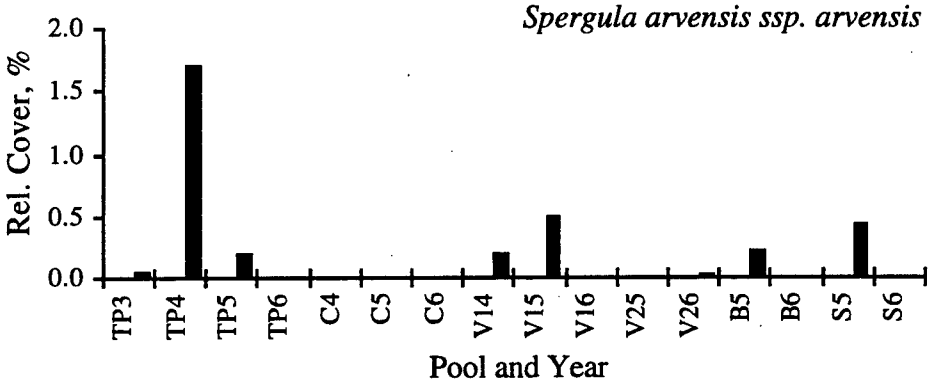

Centaurea solstitialis
Rel. Cover, %
0
1
2
3
TP3
TP4
TP5
TP6
C4
C5
C6
V14
V15
V16
V25
V26
B5
B6
S5
S6
Pool and Year


Xanthium strumarium
Rel. Cover, %
0
1
2
3
TP3
TP4
TP5
TP6
C4
C5
C6
V14
V15
V16
V25
V26
B5
B6
S5
S6
Pool and Year

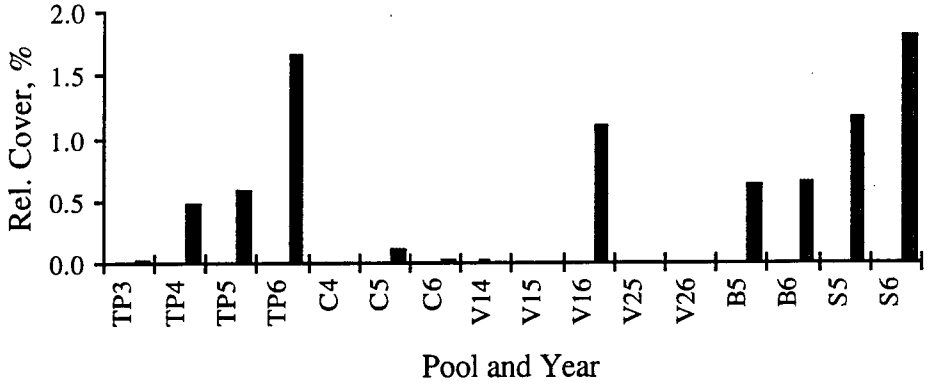

Convolvulus arvensis
Rel. Cover, %
0
2
4
6
8
10
TP3
TP4
TP5
TP6
C4
C5
C6
V14
V15
V16
V25
V26
B5
B6
S5
S6
Pool and Year


Callitriche sp.
Rel. Cover, %
2.5
2.0
1.5
1.0
0.5
0.0
TP3
TP4
TP5
TP6
C4
C5
C6
V14
V15
V16
V25
V26
B5
B6
S5
S6
Pool and Year

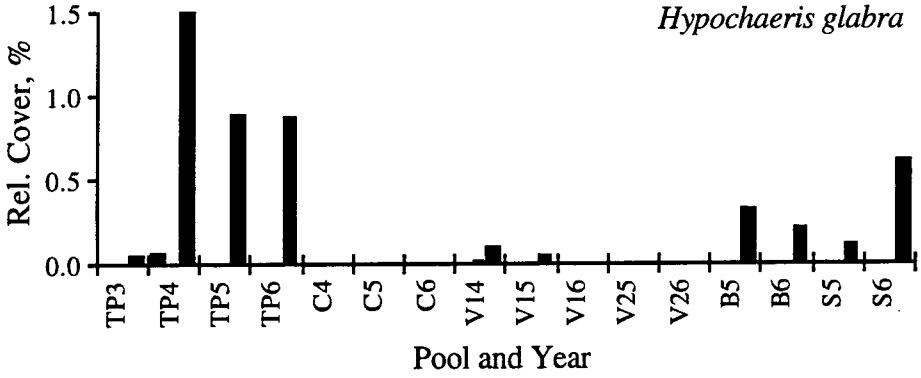

Medicago polymorpha
Rel. Cover, %
2.0
1.5
1.0
0.5
0.0
TP3
TP4
TP5
TP6
C4
C5
C6
V14
V15
V16
V25
V26
B5
B6
S5
S6
Pool and Year


Spergula arvensis ssp. arvensis
Rel. Cover, %
2.0
1.5
1.0
0.5
0.0
TP3
TP4
TP5
TP6
C4
C5
C6
V14
V15
V16
V25
V26
B5
B6
S5
S6
Pool and Year

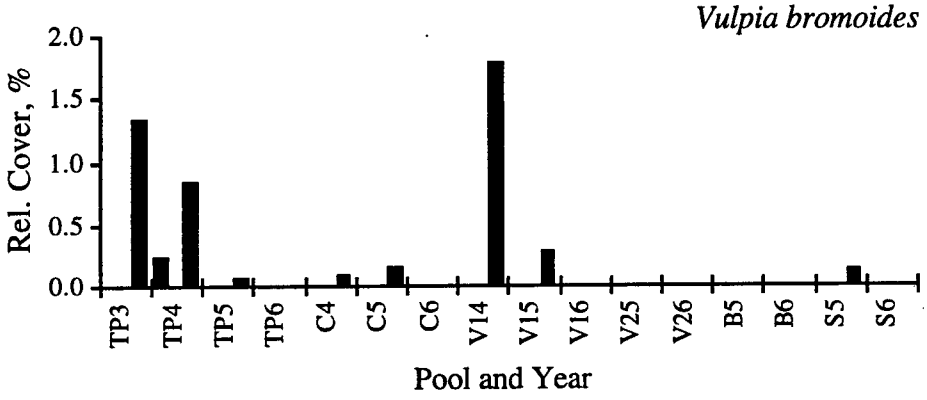
Briza minor



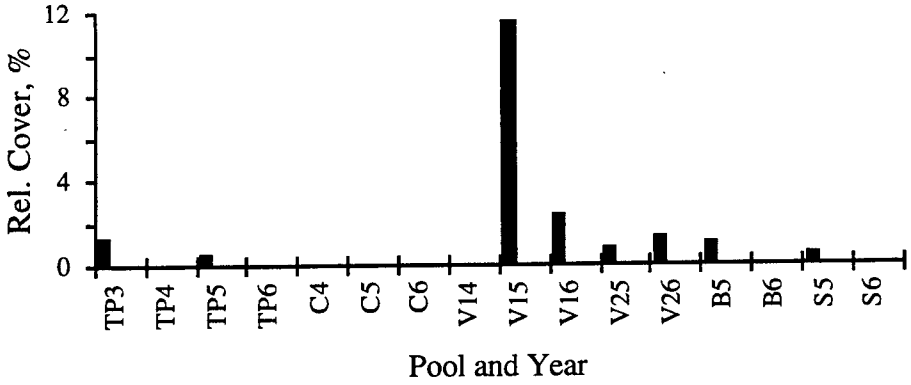
Hypochaeris glabra



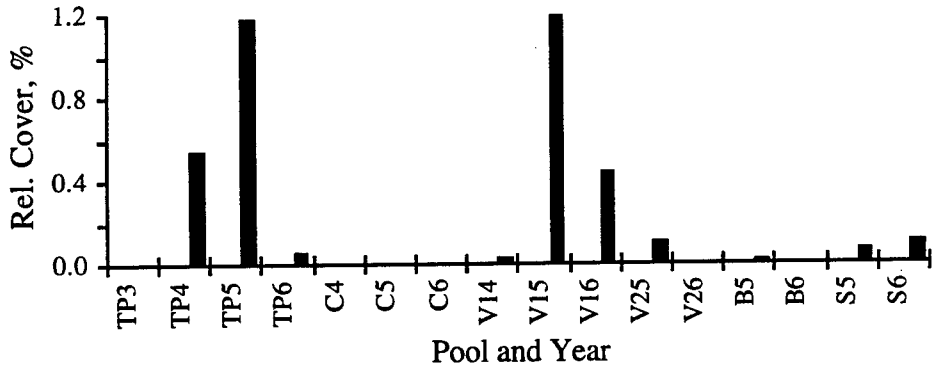
Vulpia bromoides



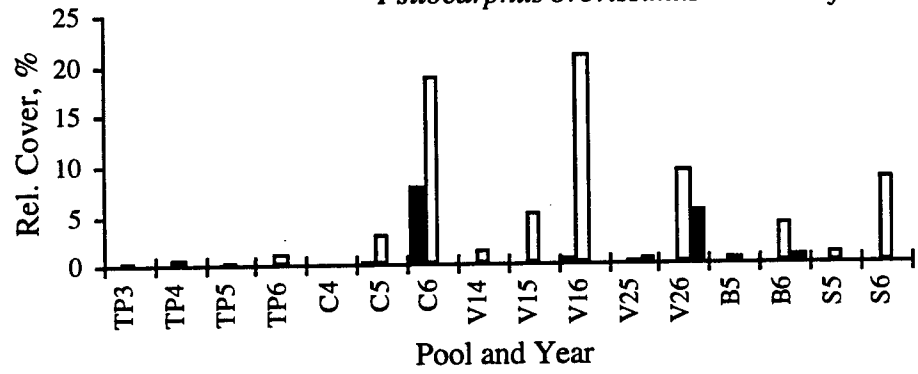
Cuscuta howelliana

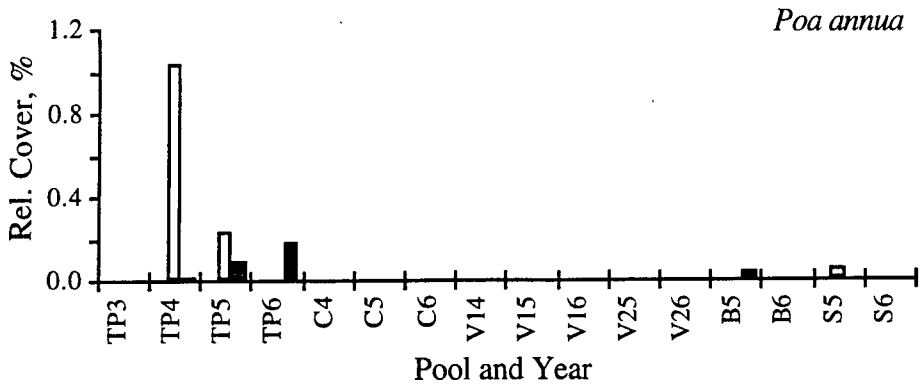


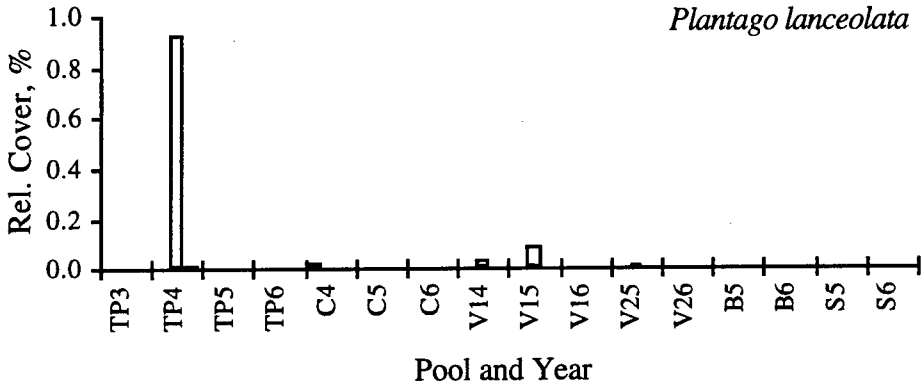
Navarretia intertexta ssp. intertexta

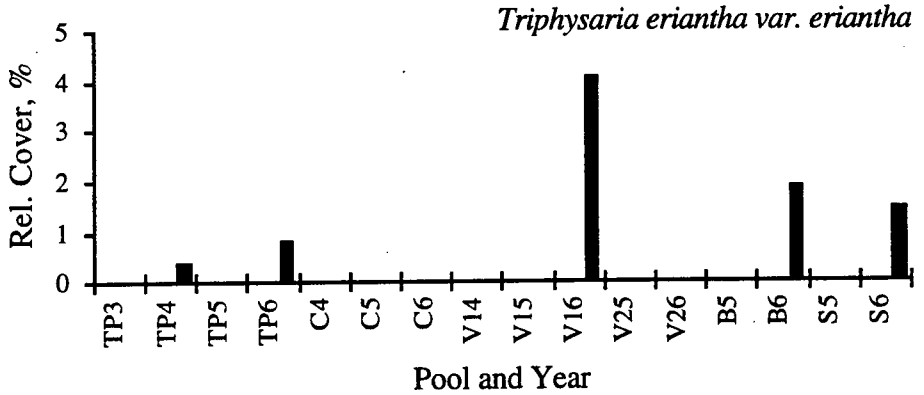


Psilocarphus brevissimus var. multiflorus

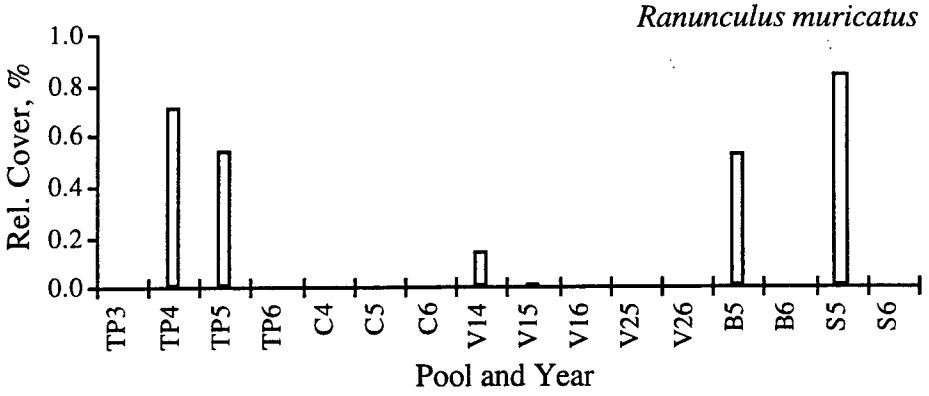



Poa annua
Rel. Cover, %
1.2
0.8
0.4
0.0
TP3
TP4
TP5
TP6
C4
C5
C6
V14
V15
V16
V25
V26
B5
B6
S5
S6
Pool and Year

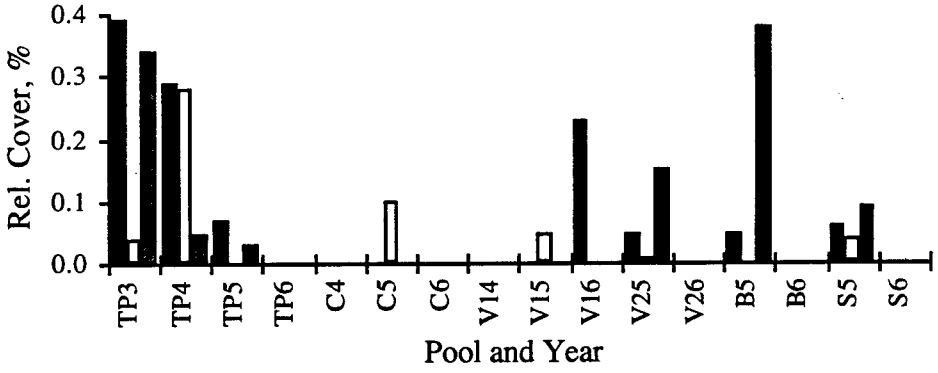

Plantago lanceolata
Rel. Cover, %
1.0
0.8
0.6
0.4
0.2
0.0
TP3
TP4
TP5
TP6
C4
C5
C6
V14
V15
V16
V25
V26
B5
B6
S5
S6
Pool and Year


Triphysaria eriantha var. eriantha
Rel. Cover, %
5
4
3
2
1
0
TP3
TP4
TP5
TP6
C4
C5
C6
V14
V15
V16
V25
V26
B5
B6
S5
S6
Pool and Year

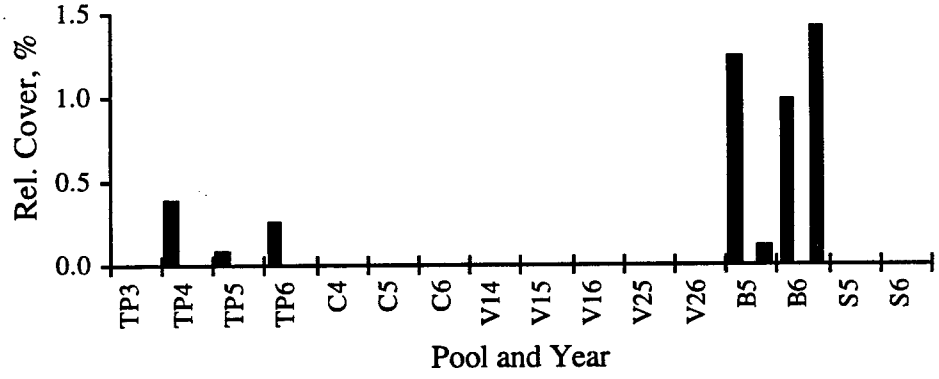
Ranunculus muricatus



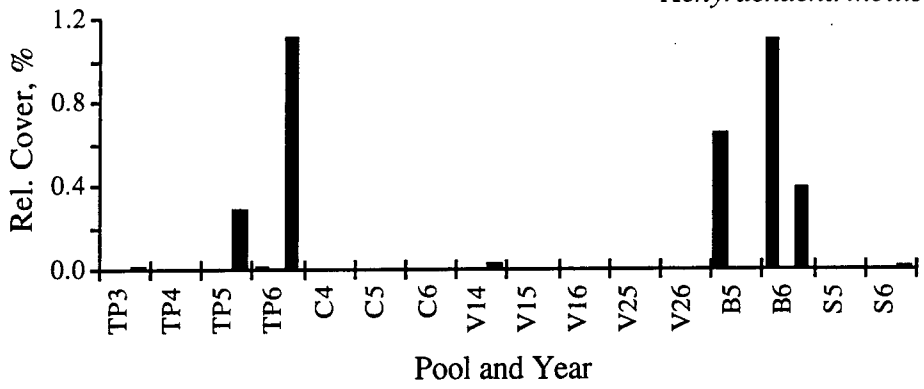
Veronica peregrina ssp. xalapensis



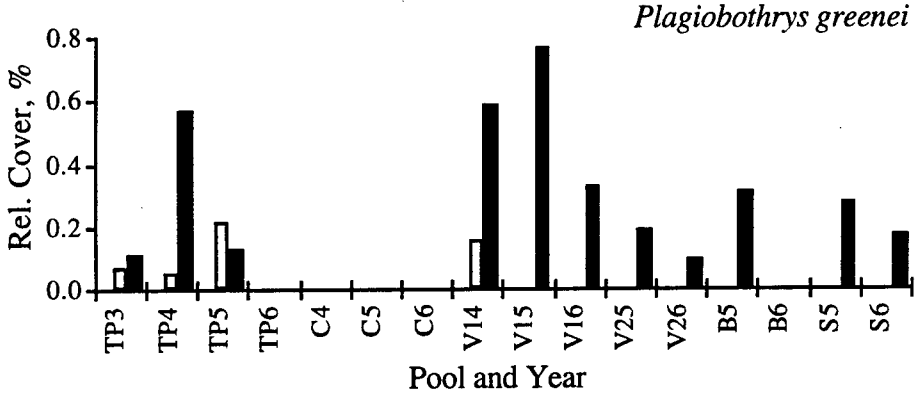
Trifolium dubium



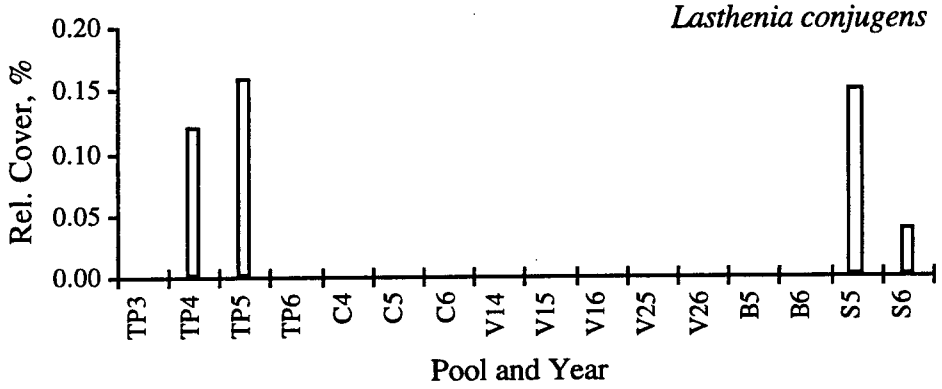
Achyrachaena mollis



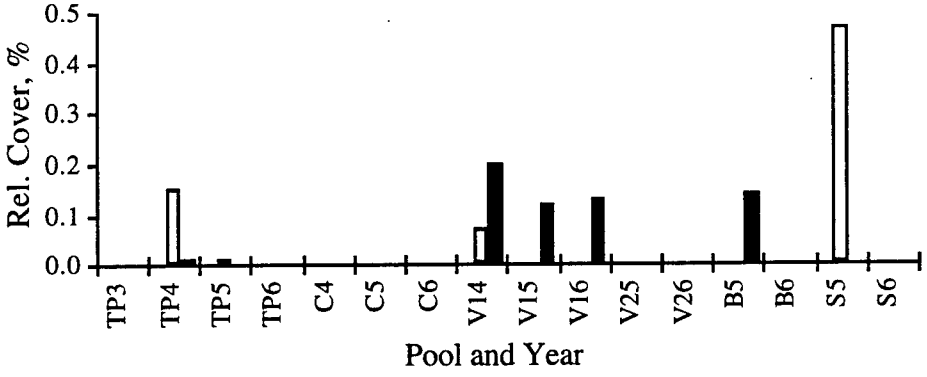
Plagiobothrys greenei



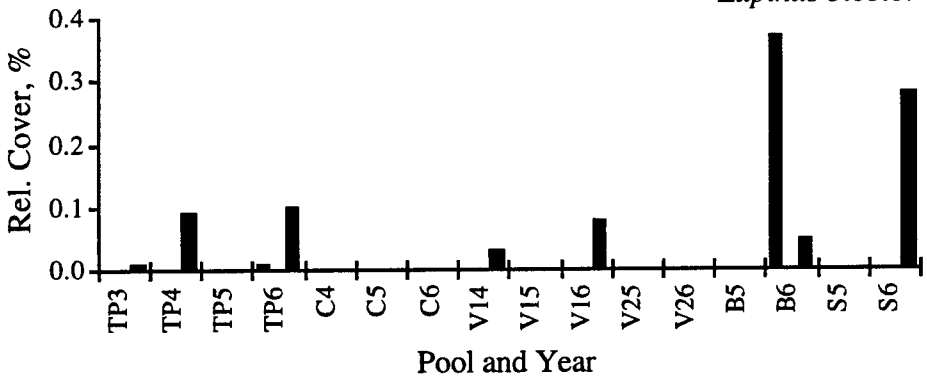
Lasthenia conjugens



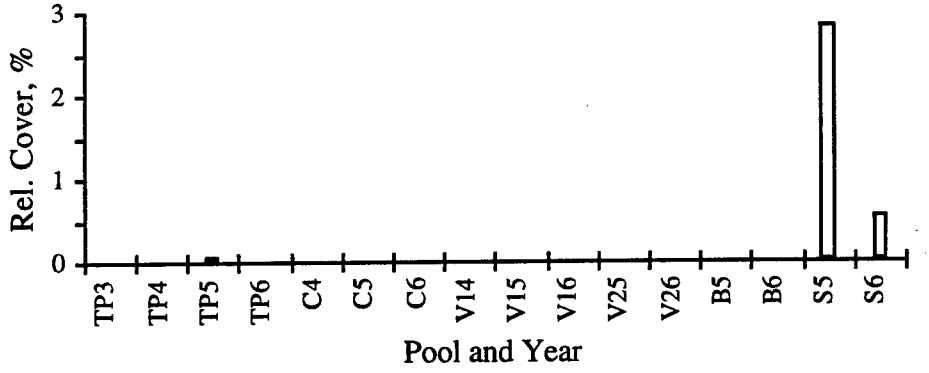
Trifolium depauperatum var. truncatum

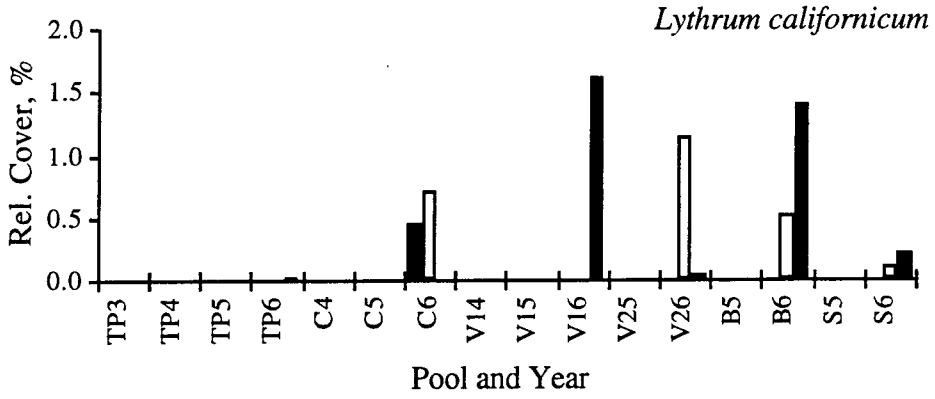


Lupinus bicolor



Trifolium oliganthum




Lythrum californicum
Rel. Cover, %
2.0
1.5
1.0
0.5
0.0
TP3
TP4
TP5
TP6
C4
C5
C6
V14
V15
V16
V25
V26
B5
B6
S5
S6
Pool and Year

Appendix C-

Supporting Data on the Affect on Source Pools of Inoculum Removal

TABLE C1-RELATIVE COVER OF SPECIES ON REFERENCE AND EXPERIMENTAL PLOTS

Each table below gives relative cover (percent cover relative to all items including non-living ones) for species in source pools and removal plots for systems A (source pool TR5), B (TR17), and C (TR1-TR4 taken together). Items are listed in order of decreasing cover for reference plots in 1994, and then alphabetically. Wetland types are from Reed (1988) as given in Table B1, Appendix B.

Table C1.1. Relative cover values for system A.

		Wetland	Reference Plots				SV1			SV2		Exc		Fill	
Scientific Name	Native	Type	93	94	95	96	94	95	96	95	96	95	96	95	96
Plagiobothrys trachycarpus	yes	FACW*	17.98	34.56	21.24	6.78	20.55	15.95	10.74	23.70	13.22	26.56	11.65	6.62	2.52
Polypogon monspeliensis	no	FACW*		12.72	23.76	13.45	7.40	20.30	13.67	16.36	19.10	26.02	18.10	6.44	18.33
Eryngium aristulatum var. aristulatum	yes	OBL	1.08	12.38	22.20	25.99	8.41	18.66	20.34	21.33	17.62	3.28	1.05	7.44	4.27
Lasthenia glaberrima	yes	OBL	2.84	7.98	9.89	1.13	1.93	2.50	0.56	1.80	0.46	7.35	1.27	0.03	
Eleocharis macrostachya	yes	OBL	17.36	7.22	7.29	12.29	3.64	4.45	5.98	1.54	11.19	2.31	6.08	2.74	3.75
Hordeum marinum ssp. gussoneanum	no	FAC	19.52	6.36			10.09	0.32	0.06	0.03	0.02				0.02
Lolium multiflorum	no	FAC		4.00	0.11		7.85	5.91	8.66	0.32				3.72	4.41
Eremocarpus setigerus	yes	UPL	0.60	3.29	2.05	2.01	1.41	8.68	2.70	6.26	5.08	2.38	9.17	4.51	1.19
Lythrum hyssopifolium	no	FACW	0.29	2.93	0.18	1.63	17.58	6.10	3.58	3.95	3.35	2.96	5.02	2.45	6.35
Convolvulus arvensis	no	UPL	0.17	2.48	1.64	1.82	1.93	2.94	1.59	2.99	0.40	3.52	1.34	2.31	0.55
Rumex crispus	no	FACW	2.09	1.91	1.90	10.02	0.63	1.26	5.11	0.98	6.19	0.09	8.96	2.81	6.21
Cotula coronopifolia	no	FACW+	0.23	1.31	3.02	2.83	0.49	2.45	3.06	2.75	4.81	3.11	1.45	3.06	15.95
Erodium botrys	no	UPL	0.34	1.07			4.72								
unidentified plant	poss.	UPL		0.47											
Cuscuta howelliana	yes	UPL		0.46		0.12				1.52					
Downingia concolor	yes	OBL	18.76	0.33	3.78	1.07	0.45	0.54	0.81	10.41	1.69	17.00	1.55	14.79	5.54
Juncus bufonius	yes	OBL		0.13			5.84	5.82	0.24	1.34		0.40		5.90	1.05
Geranium dissectum	no	UPL	0.43	0.06			0.02							0.09	
Hemizonia pungens	yes	FAC		0.02								0.02			
Plagiobothrys stipitatus var. micranthus	yes	OBL		0.02		0.09	0.45				0.09				
Vulpia bromoides	no	FACW		0.02			0.89	0.36							
Achyrachaena mollis	yes	FAC							0.14						0.13
Agrostis elliottiana	yes	FACW						0.35	0.03	0.56		0.47		0.37	0.02
Bellardia trixago	no	UPL													0.31
Brassica nigra	no	UPL												0.06	
Briza minor	no	FACW-												0.84	0.99
Bromus hordeaceus	no	FACU					1.06		0.06						
Centaurea solstitialis	no	UPL					0.34	0.72						0.47	0.07
Centaurea calcitrapa	no	UPL					0.02								
Cerastium glomeratum	no	UPL	0.09												
Crassula aquatica	yes	OBL	2.58				0.10	0.02		0.43	0.06	0.60	0.63	0.37	0.35
Cyperus eragrostis	yes	FACW										0.23		0.79	

Table C1.1, continued. Relative cover values for system A.

Scientific Name	Native	Wetland Type	Reference Plots 93	94	95	96	SV1 94	95	96	SV2 95	96	Exc 95	96	Fill 95	96
Deschampsia danthonoides	yes	FACW					0.02								
Epilobium brachycarpum	yes	UPL							0.03					0.26	
Hemizonia parryi	yes	FAC						0.04		0.12		0.04			0.02
Hypochaeris glabra	no	UPL					0.02								
Lilaea scilloides	yes	OBL							0.07		0.25		0.08		
Madia elegans	yes	UPL													0.96
Medicago polymorpha	no	UPL													0.16
Polygonum arenastrum	no	FAC			0.10	0.99		0.17	1.65	0.56	3.49	0.54	3.26	1.34	4.32
Psilocarphus brevissimus var. multiflorus	yes	OBL													0.18
Rumex acetosella	no	NI												0.30	0.36
Silene gallica	no	UPL												0.26	0.02
Sonchus asper	no	FAC						0.17							
Trifolium dubium	no	FACU*					1.93		1.59						1.75
Veronica peregrina ssp. xalapensis	yes	OBL	0.27		0.05		0.38			0.24	0.02			0.20	0.05
Vicia villosa ssp. villosa	no	UPL					1.45		0.87					1.85	1.46
Xanthium strumarium	yes	FAC+			2.37	2.44		0.67	2.57	0.47	0.84	0.09	3.57	0.93	2.12
SUMMARIES															
Total non-living			15.37	0.74	0.42	17.34	0.41	1.63	15.89	2.35	12.12	3.01	26.82	29.05	16.58
(dead algal mats)					0.34	10.20		0.54	14.82	0.94	7.73		9.89		5.37
(bare ground)			13.93	0.05		1.54	0.37	0.08		1.10	0.73	3.01	14.91	29.05	11.02
(rock)			1.44	0.23			0.10			0.11	0.07		0.20		
(thatch)					0.08	5.60		1.01	1.07	0.20	3.60		1.82		0.18
Native upland annuals			0.60	3.76	2.05	2.13	1.41	8.68	2.73	7.78	5.08	2.38	9.17	4.77	2.15
Native wetland annuals			42.43	43.04	37.32	11.51	29.72	25.89	15.17	39.07	16.63	52.54	18.75	29.21	12.00
Native upland perennials															
Native wetland perennials			18.44	19.60	29.49	38.28	12.04	23.11	26.32	22.87	28.81	5.83	7.14	10.98	8.03
Non-native upland annuals			0.86	1.13			9.56	0.72	2.51					2.73	3.76
Non-native wetland annuals			19.81	26.04	24.15	16.07	43.81	33.33	27.62	21.21	25.95	29.52	26.38	14.79	34.42
Non-native upland perennials			0.17	2.48	1.64	1.82	1.93	2.94	1.59	2.99	0.40	3.52	1.34	2.61	0.90
Non-native wetland perennials			2.31	3.22	4.92	12.84	1.12	3.71	8.17	3.73	11.00	3.19	10.41	5.87	22.16

Table C1.2. Relative cover values for system B.

Scientific Name	Native	Wetland Type	Reference Plots				SV1			SV2		Exc		Fill	
			93	94	95	96	94	95	96	95	96	95	96	95	96
Plagiobothrys stipitatus var. micranthus	yes	OBL	22.61	26.02	6.73	0.84	21.73	3.66	4.29	8.33	3.15	17.66	1.18	4.61	4.29
Hordeum marinum ssp. gussoneanum	no	FAC	5.40	14.07	18.05	3.70	7.39	29.59	6.69	4.64	1.46	0.85		3.41	2.26
Lasthenia glaberrima	yes	OBL	11.02	12.59	29.42	5.51	13.88	31.81	2.81	17.36	3.49	23.60	3.35	2.01	0.84
Deschampsia danthonioides	yes	FACW	0.32	12.02	3.97		7.54	2.19		19.33	0.80	0.68		2.09	0.14
Rumex crispus	no	FACW	1.42	7.49	2.86	7.75		0.20	3.45	1.43	2.26		0.65		1.47
Hemizonia pungens	yes	FAC		4.81	0.36	1.11	9.80	0.43	0.86	0.03	0.37	0.07	0.36	0.73	0.89
Picris echioides	no	FAC*		3.29	0.66	1.66	4.80	6.36	1.51	0.10	0.12		0.14		0.04
Lythrum hyssopifolium	no	FACW	2.47	3.27	0.12	0.49	6.93	2.47	3.89	3.41	13.52	2.87	3.90	3.94	7.78
Medicago polymorpha	no	UPL		2.39			3.38								
Cotula coronopifolia	no	FACW+	3.44	1.85	0.78	0.26	1.76	0.58	1.64	17.72	10.38	1.46	0.33	3.01	10.59
Lolium multiflorum	no	FAC	1.67	1.75	3.25	3.00	2.88	8.29	13.43	2.19	1.23	0.22		16.35	4.65
Polypogon monspeliensis	no	FACW*	0.16	1.61	14.79	12.77	1.38	9.11	16.97	13.56	19.69	4.73	2.89	5.82	23.79
Poa annua	no	FACW		1.53			0.37	0.18	0.11			0.04			
Ranunculus muricatus	no	FACW		1.38	0.97		0.14			0.21					
Downingia concolor	yes	OBL	2.70	1.36	3.50	0.09	0.19	0.78	0.03	8.45	2.81	17.47	0.50	9.55	11.24
Plagiobothrys trachycarpus	yes	FACW*	0.87	1.31			0.51								
Trifolium willdenovii	yes	UPL		1.02			0.54								
Eremocarpus setigerus	yes	UPL		0.82											
Juncus bufonius	yes	OBL	2.52	0.76			6.23							4.02	
Trifolium depauperatum var. truncatum	yes	FAC-		0.27											
Convolvulus arvensis	no	UPL	0.16	0.13			0.64								
Erodium botrys	no	UPL		0.12		0.04	2.84				0.04				
Geranium dissectum	no	UPL		0.05				0.04							
Callitriche marginata	yes	OBL	0.73	0.04								1.50		0.44	
Alopecurus saccatus	yes	OBL				0.14				0.58		0.45			
Cerastium glomeratum	no	UPL						0.07							
Crassula aquatica	yes	OBL	0.08									0.96		0.13	
Downingia insignis	yes	OBL			0.28										
Downingia pulchella	yes	OBL				0.04		0.40							
Eryngium aristulatum var. aristulatum	yes	OBL			1.76	4.87			0.57				1.42	0.13	
unidentified grass													0.24		
Lasthenia conjugens	yes	FACW										0.58			
Lilaea scilloides	yes	OBL			0.50						1.62		1.70		
Pilularia americana	yes	OBL	6.02									0.03	0.50	6.95	0.78

Table C1.2, continued. Relative cover values for system B.

Scientific Name	Native	Wetland Type	Reference Plots 93	94	95	96	SV1 94	95	96	SV2 95	96	Exc 95	96	Fill 95	96
Plagiobothrys greenei	yes	FACW	0.56				0.19	0.10		0.10		1.14		0.39	
Plantago lanceolata	no	FAC-					1.53		0.67						
Pleuropogon californicus	yes	OBL			5.90	34.57		3.50	10.87	1.05	16.06	4.00	3.76	4.84	11.74
Polygonum arenastrum	no	FAC				0.40			3.68		0.86		0.62		
Psilocarphus brevissimus var. multiflorus	yes	OBL	0.30		0.61	0.90				0.17	0.11	2.41	4.98	0.47	3.47
Rumex pulcher	no	FAC+			0.32										
Trifolium oliganthum	yes	UPL			0.12			0.10		0.17					
Veronica peregrina ssp. xalapensis	yes	OBL	0.09				0.33	0.03				0.08		0.39	
SUMMARIES															
Non-living			37.45	0.08	5.06	21.87	2.38	0.11	28.52	1.14	22.02	19.20	73.72	30.72	16.03
(dead algal mats)						3.30			13.96		15.82		72.06		10.34
(bare ground)			37.45	0.08	5.06	1.07	2.38	0.11		1.04	0.22	13.48		30.72	0.32
(thatch)						17.49			14.56	0.10	5.98	5.72	1.42		5.36
Native upland annuals				1.84	0.12		2.71	0.10		0.17					
Native wetland annuals			41.79	59.18	51.27	43.20	59.94	42.91	18.86	55.42	28.41	70.59	15.83	29.67	32.60
Native upland perennials															
Native wetland perennials			6.02		1.76	4.87			0.57			0.03	1.91	7.08	0.78
Non-native upland annuals				2.55		0.04	7.15	0.11			0.04				
Non-native wetland annuals			9.71	26.89	37.84	22.02	23.88	56.00	46.28	24.12	36.89	8.71	7.55	29.52	38.52
Non-native upland perennials			0.16	0.13			0.64								
Non-native wetland perennials			4.87	9.33	3.96	8.00	3.29	0.78	5.76	19.15	12.64	1.46	0.99	3.01	12.06

Table C1.3. Relative cover values for system C.

Scientific Name	Native	Wetland Type	Reference Plots				SV1			SV2		Exc		Fill	
			93	94	95	96	94	95	96	95	96	95	96	95	96
Plagiobothrys trachycarpus	yes	FACW*	7.28	16.34	13.82	7.71	8.39	2.63	7.57	16.88	6.63	13.89	9.32	6.3	1.97
Plagiobothrys stipitatus var. micranthus	yes	OBL		13.23	4.59	2.28	4.60	3.38	0.12	2.49	1.67	4.47	0.3	1.74	0.27
Pleuropogon californicus	yes	OBL	9.24	8.66	16.33	12.11	4.37	15.13	8	8.97	7.33	4.86	1.54	2.28	1.12
Hordeum marinum ssp. gussoneanum	no	FAC	1.71	6.94	3.57	1.71	6.29	2.86	1.22	3.66	1.99				0.07
Erodium botrys	no	UPL	11.64	6.25	0.1		8.93	0.76	0.97	0.2	0.02			0.47	0.13
Deschampsia danthonioides	yes	FACW	0.04	6.15	13.4	13.85	1.73	9.77	5.68	6.44	12.18	7.02	9.35	3.97	12.01
Cotula coronopifolia	no	FACW+		5.82	3.95	20.44	4.31	5.72	8.37	11.8	22.01	5.54	16.84	4.6	16.94
Centaurea calcitrapa	no	UPL		5.06			5.61								
Juncus bufonius	yes	OBL	9.49	4.16	2.51	0.54	14.93	7.31	2.86	4.2	0.3	1.2		10.47	3.25
Downingia concolor	yes	OBL	0.06	3.93	3.36	10.27	0.46	1.1	4.92	8.38	11.71	23.77	16.98	23.89	27.42
Lythrum hyssopifolium	no	FACW	4.46	3.56	2.56	0.71	3.91	4.87	2.46	3.62	1.31	0.22	0.13	4.39	2.41
Alopecurus saccatus	yes	OBL		2.93	0.36	0.18			0.11	0.08	0.09				0.06
Convolvulus arvensis	no	UPL	0.99	2.71	1.94	1.21	1.46	2.75	0.36	5.23	0.07	1.41	0.03	2.09	0.79
Spergula arvensis ssp. arvensis	no	UPL	0.14	2.31	0.62		3.40	3.74	0.06			0.62		1.92	0.54
Avena sativa	no	UPL		2.26			0.40								
Centaurea solstitialis	no	UPL		1.74			1.93							0.26	
Lolium multiflorum	no	FAC	5.66	1.27	4.99	4.51	5.56	10.63	13.46	4.53	9.72	0.68		2.54	3.67
Plagiobothrys greenei	yes	FACW		1.16	0.04		0.21	0.61		0.11					
Vulpia bromoides	no	FACW	16.12	0.49	0.29			0.5		0.16					
Navarretia intertexta ssp. intertexta	yes	OBL		0.48	0.19					0.59		0.49		0.22	0.06
Hypochaeris glabra	no	UPL	0.06	0.4			0.10	1.33	1.18		0.03			0.94	0.64
Medicago polymorpha	no	UPL		0.31			0.10		0.09		0.82				0.2
Rumex crispus	no	FACW		0.24	0.32		0.18	0.89		0.2	0.09				0.15
unidentified grass	poss.	UPL		0.2											
Polypogon monspeliensis	no	FACW*	0.09	0.16	9.14	12.83	0.34	4.98	8.32	10.97	13.24	8.26	20.07	3.84	14.35
Triteleia hyacinthina	yes	FACW*		0.16											
Triphysaria eriantha var. eriantha	yes	UPL		0.13			2.56		2.27						0.41
Veronica peregrina ssp. xalapensis	yes	OBL	0.2	0.1	0.31		0.14	0.75		0.85		1.15		0.55	
Avena fatua	no	UPL		0.06										0.22	
Eremocarpus setigerus	yes	UPL	0.13	0.06	3.68	1.63	0.17	3.16	1.43	0.61	0.12	0.56	0.32	0.98	0.11
Lupinus bicolor	yes	UPL	0.28	0.06			0.17								0.31
unidentified plant	poss.	UPL	0.72	0.05											

Table C1.3, continued. Relative cover values for System C.

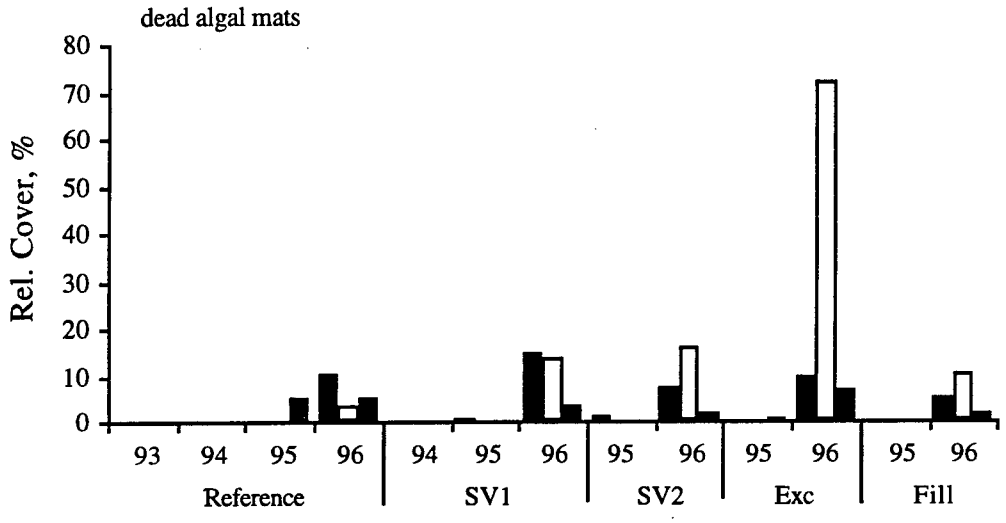
Scientific Name	Native	Wetland Type	Reference Plots				SV1			SV2		Exc		Fill	
			93	94	95	96	94	95	96	95	96	95	96	95	96
Rumex acetosella	no	NI		0.03								0.07		0.17	
Anagallis arvensis	no	FAC		0.02		0.03	0.30							0.03	
Achyrachaena mollis	yes	FAC					0.80	0.75	1.69	0.07	0.92				
Aira caryophyllea	no	UPL								0.25					
Avena barbata	no	UPL					0.70							0.19	
Bellardia trixago	no	UPL					0.80								0.03
Brassica nigra	no	UPL												0.38	
Briza minor	no	FACW-					0.94	3	3.1	0.09	0.36			0.37	0.08
Bromus diandrus	no	UPL	4.69												
Brodiaea elegans	yes	FACU					0.16	0.39		0.04					
Brodiaea elegans ssp. elegans	yes	FACU	0.04												
Bromus hordeaceus	no	FACU					0.33	0.44	0.57					0.11	0.15
Calandrinia ciliata	yes	FACU*					0.65	0.07				0.07			
Callitriche marginata	yes	OBL									0.02				
Callitriche sp.	yes	OBL	1.48												
Centunculus minimus	yes	OBL								0.02					
Crassula aquatica	yes	OBL	5.37		0.03		0.30			1.33	0.05	0.58	5.38	0.1	0.05
Epilobium brachycarpum	yes	UPL					0.79	0.02	0.2						
Epilobium densiflorum	yes	OBL						0.31		0.14		0.05		0.71	
Filago gallica	no	UPL						0.69	0.03	0.04		0.21		0.33	0.03
Gastridium ventricosum	no	UPL												0.11	
Geranium dissectum	no	UPL	3.43					0.29							
Hemizonia parryi	yes	FAC			2.6	0.18		2.74	1.23	4.89	0.54	0.17		1.6	0.61
Lasthenia glaberrima	yes	OBL			0.27			1.16							0.45
Lilaea scilloides	yes	OBL	0.44			0.62			9.53		1.48		2.49		0.81
Lythrum californicum	yes	OBL							0.86						0.3
Mimulus guttatus	yes	OBL							0.13					0.06	
moss	poss.	UPL							0.03						
Pilularia americana	yes	OBL			0.07			0.17	1.03		0.86	1.07	0.56	5.51	0.72
Poa annua	no	FACW						0.75		0.6	0.14				
Polygonum arenastrum	no	FAC			0.47	1.57		2.1	4.95	0.17	0.52	0.22	1.52	0.11	0.58
Psilocarphus brevissimus var. multiflorus	yes	OBL			0.03	0.12	0.20	0.94		0.02	0.05		0.62	0.15	

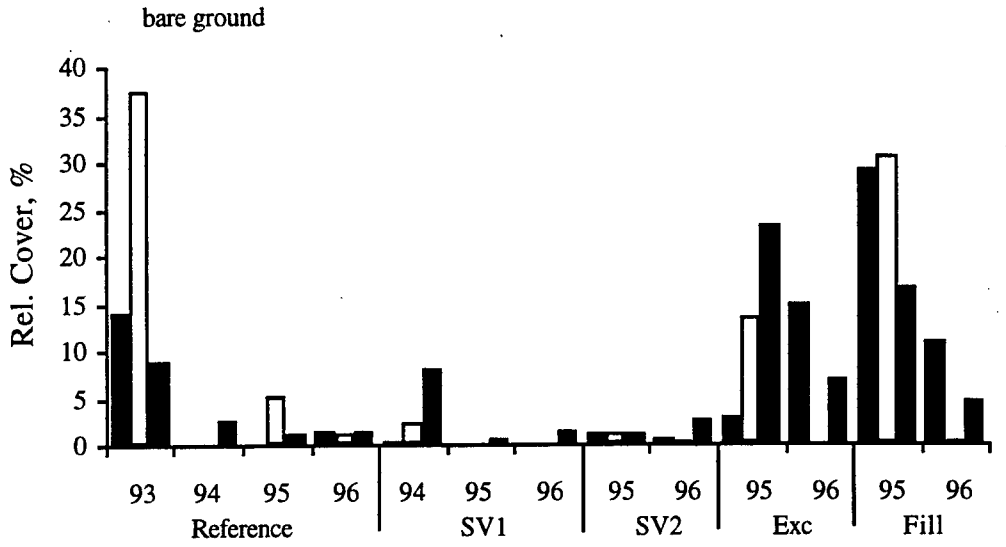
Table C1.3, continued. Relative cover values for System C.

Scientific Name	Native	Wetland Type	Reference Plots 93	94	95	96	SV1 94	95	96	SV2 95	96	Exc 95	96	Fill 95	96
Silene gallica	no	UPL	0.43				0.11	0.37						0.05	
Trifolium depauperatum var. truncatum	yes	FAC-	0.14				0.20	0.19							
Veronica persica	no	UPL									0.27				0.05
Vicia sativa	no	FACU	6.7						0.34						
Vicia villosa ssp. villosa	no	UPL												1.62	2.3
Vulpia myuros	no	FACU							0.09		0.27				0.1
SUMMARIES															
Non-living			9.68	2.82	10.47	7.5	8.15	2.74	6.81	2.34	5.18	23.43	14.55	16.72	6.89
(dead algal mats)					4.92	5.05		0.08	3.43	0.14	1.66	0.39	6.99	0.12	1.89
(bare ground)			8.8	2.57	1.13	1.34	8.15	0.52	1.32	1.3	2.46	23.04	6.93	16.59	4.64
(rock)			0.16												
(thatch)					4.42	1.11		2.14	2.03	0.9	1.06		0.63		0.36
Native upland annuals			0.42	0.25	3.68	1.63	4.34	3.26	3.9	0.61	0.12	0.63	0.32	0.98	0.82
Native wetland annuals			33.74	57.14	57.83	47.86	43.62	46.78	41.84	55.48	42.97	57.65	45.98	52.04	48.07
Native upland perennials			0.04				0.16	0.39		0.04					
Native wetland perennials				0.16	0.07			0.17	1.89		0.86	1.07	0.56	5.51	1.02
Non-native upland annuals			27.1	18.39	0.72		2.72	7.62	3.33	0.49	1.42	0.83		6.6	4.16
Non-native wetland annuals			28.03	12.44	21.02	21.36	17.70	29.69	33.51	23.81	27.28	9.38	21.72	11.29	21.16
Non-native upland perennials			0.99	2.74	1.94	1.21	1.46	2.75	0.36	5.23	0.07	1.47	0.03	2.26	0.79
Non-native wetland perennials				6.06	4.27	20.44	4.49	6.61	8.37	12	22.1	5.54	16.84	4.6	17.09

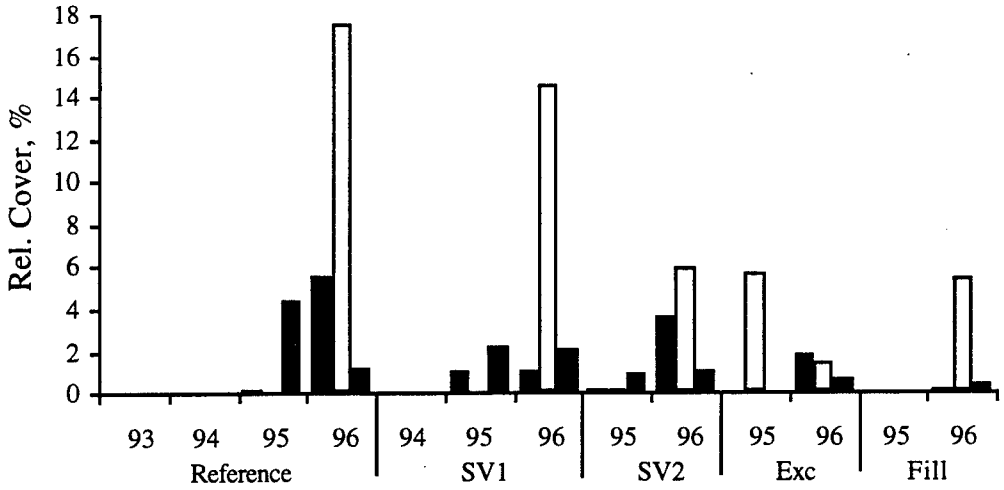
FIGURE C1-GRAPHS OF RELATIVE COVER OF PLANT SPECIES AND THREE NON-LIVING ITEMS ON REFERENCE AND EXPERIMENTAL PLOTS.

Each graph shows the average relative cover for items in each year and plot type on the x-axis. Some species with very low values (Table C1) are not shown. "SV1" stands for the scrape/vacuum removal method applied in 1993 with data collection beginning in 1994; "SV2" for this same technique applied first in 1994 with data collection beginning 1995; "Exc" for the excavation method in which plots were left unmodified after soil removal, applied in 1994 and data first taken in 1995, and "Fill" for plots that were filled to level with upland soil after blocks were removed, applied in 1994 and data first taken in 1995. Black bars represent pool system A, white bars B, and gray bars C.

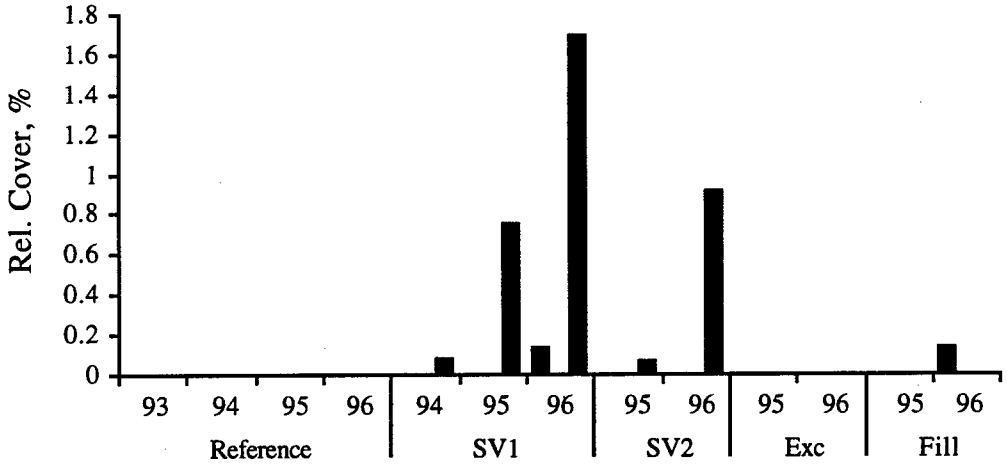




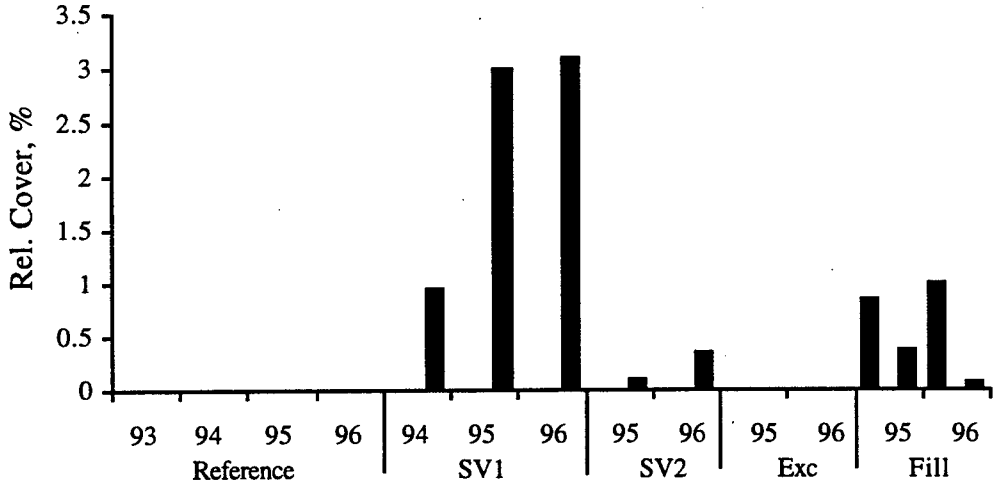
thatch



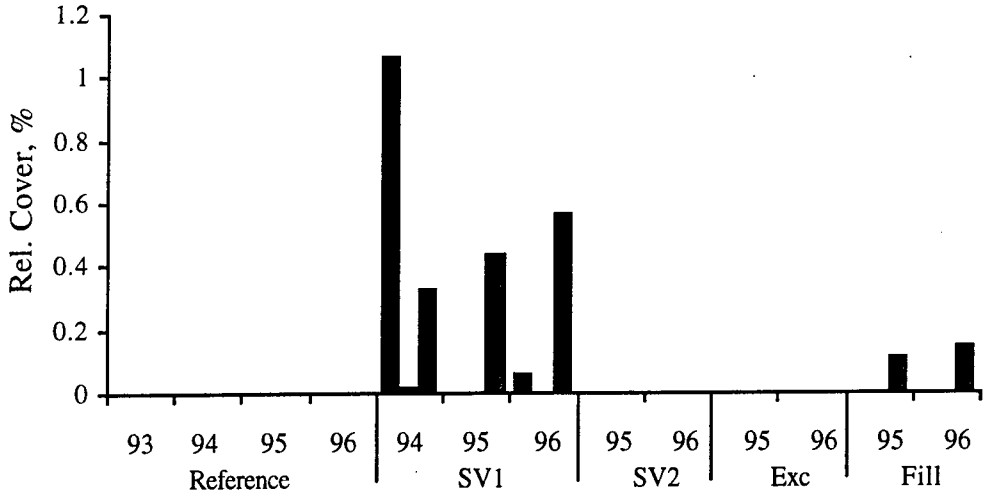
Achyrachaena mollis



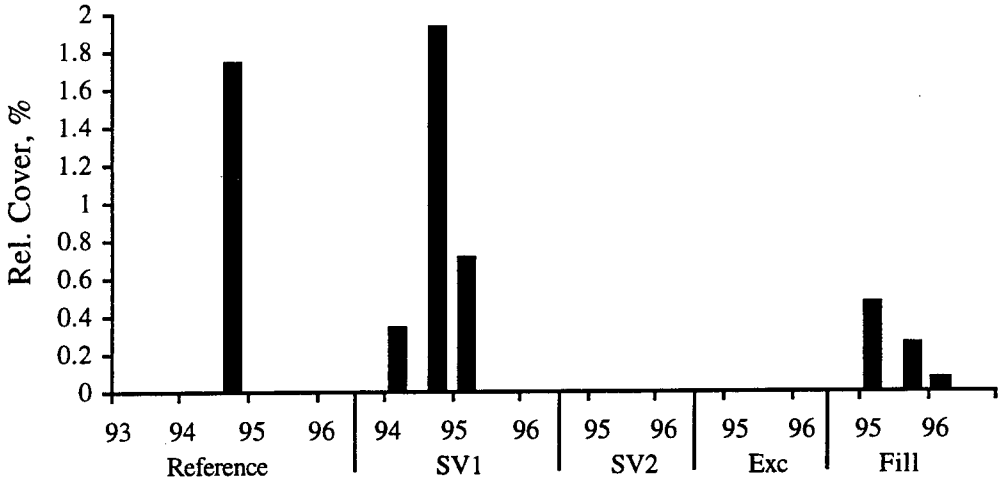
Briza minor



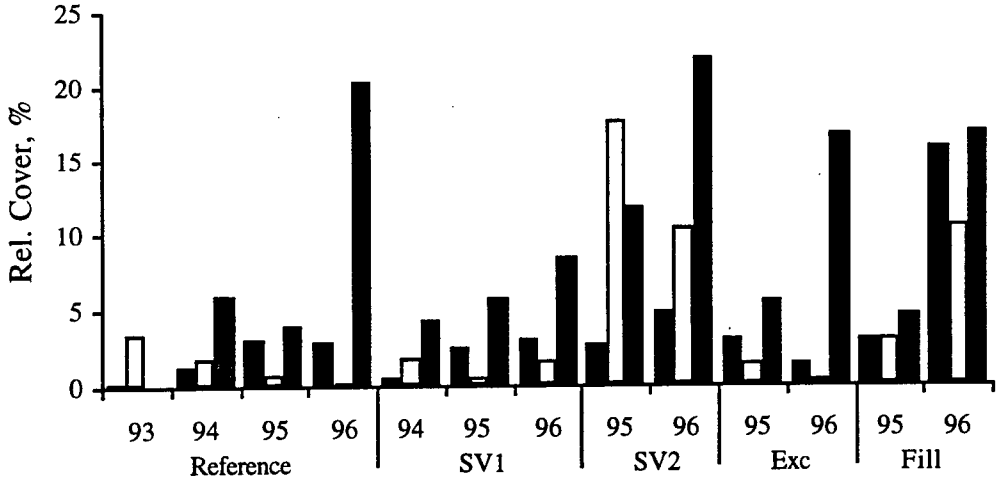
Bromus hordeaceus



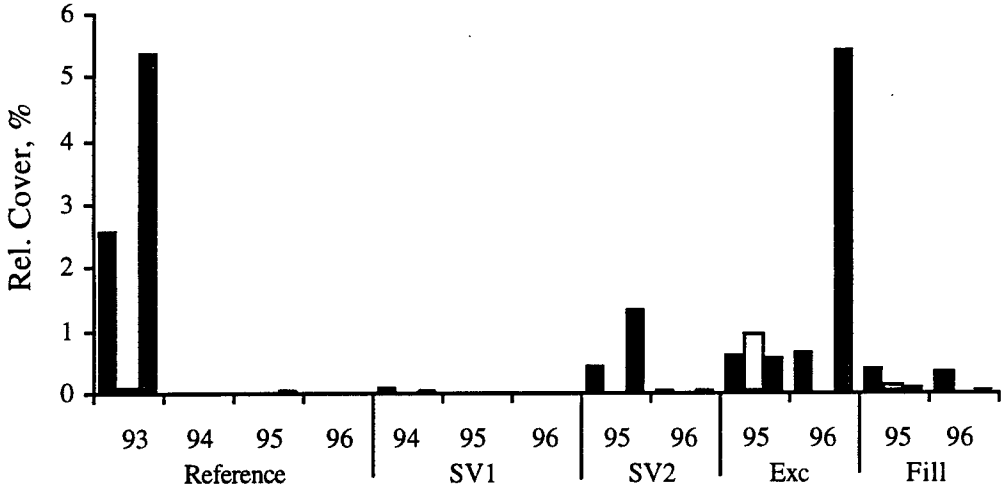
Centaurea solstitialis



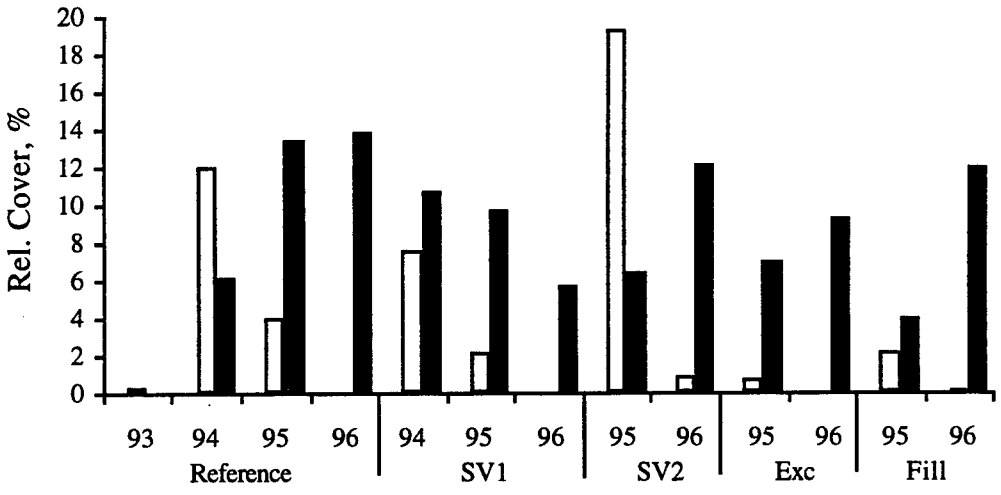
Cotula coronopifolia



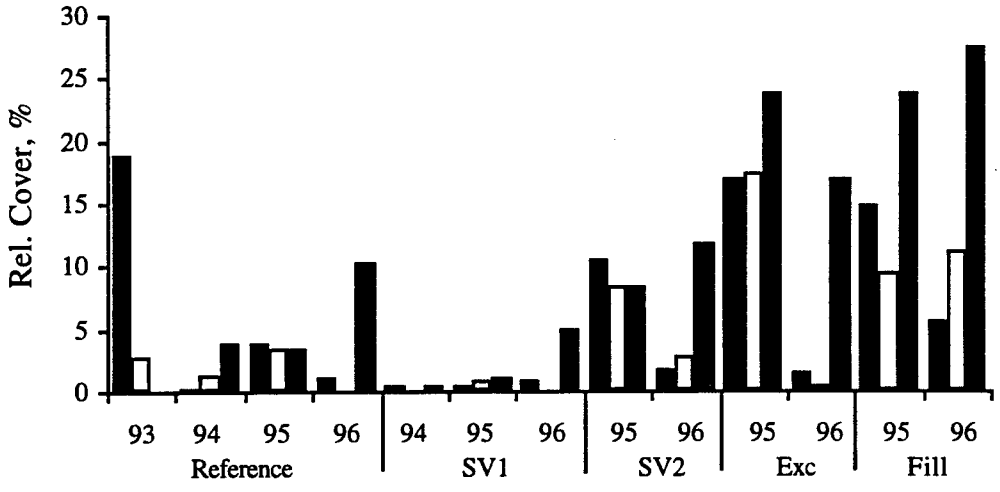
Crassula aquatica



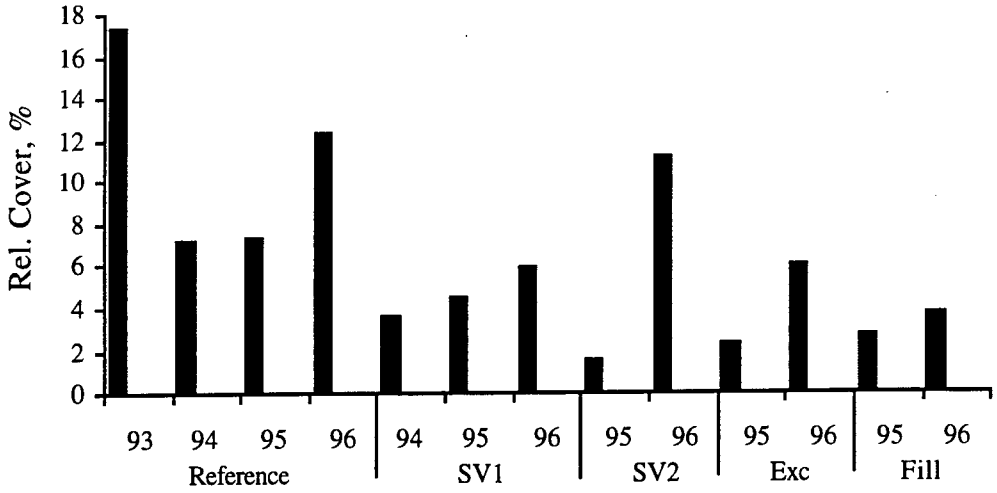
Deschampsia danthonioides



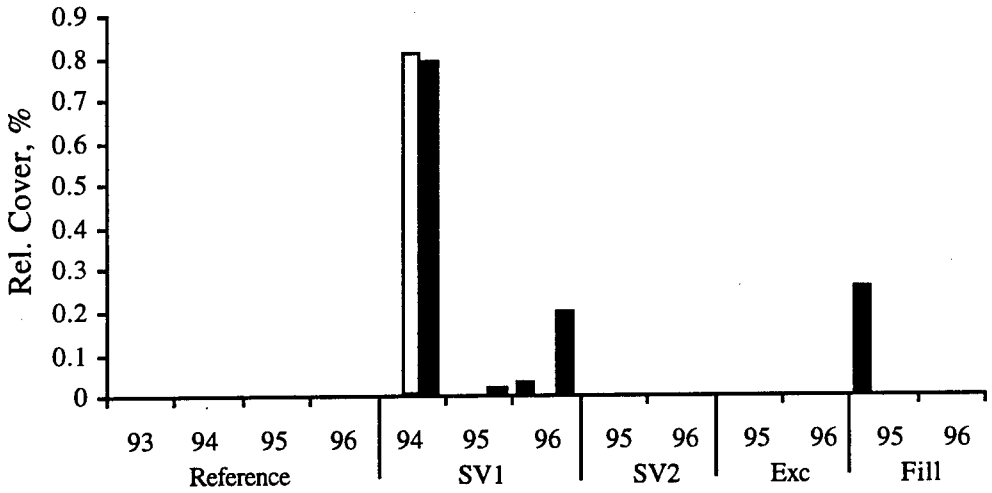
Downingia concolor



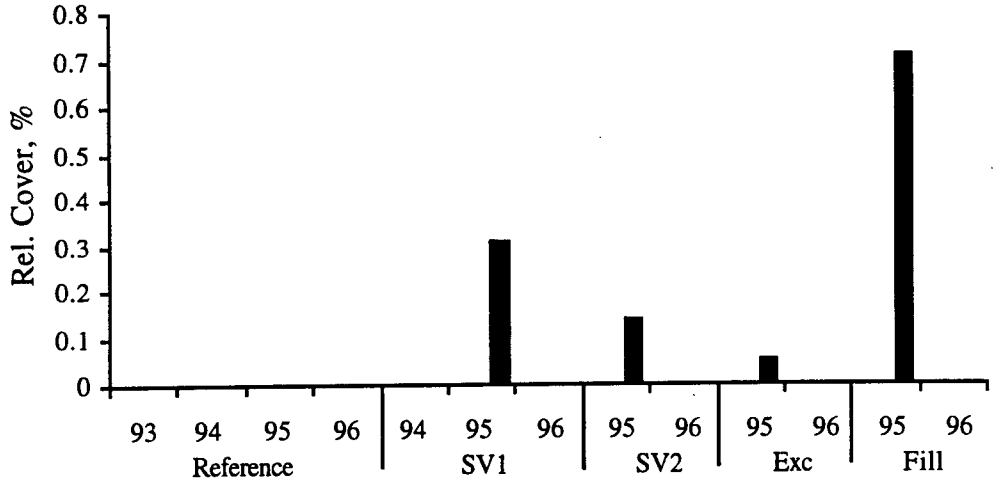
Eleocharis macrostachya



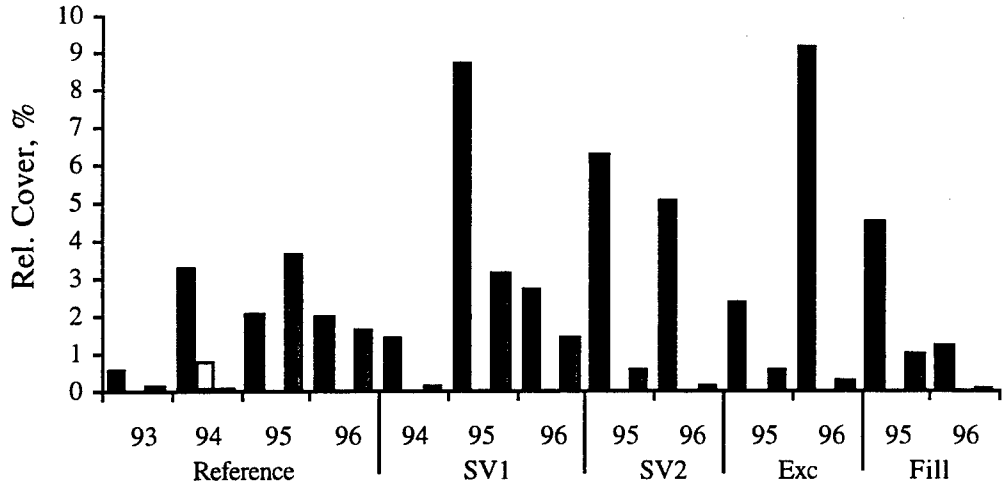
Epilobium brachycarpum



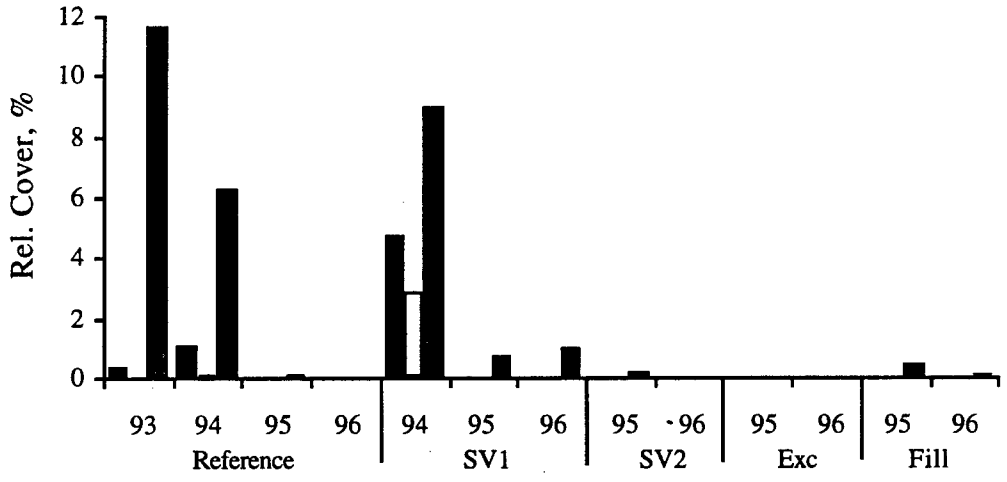
Epilobium densiflorum



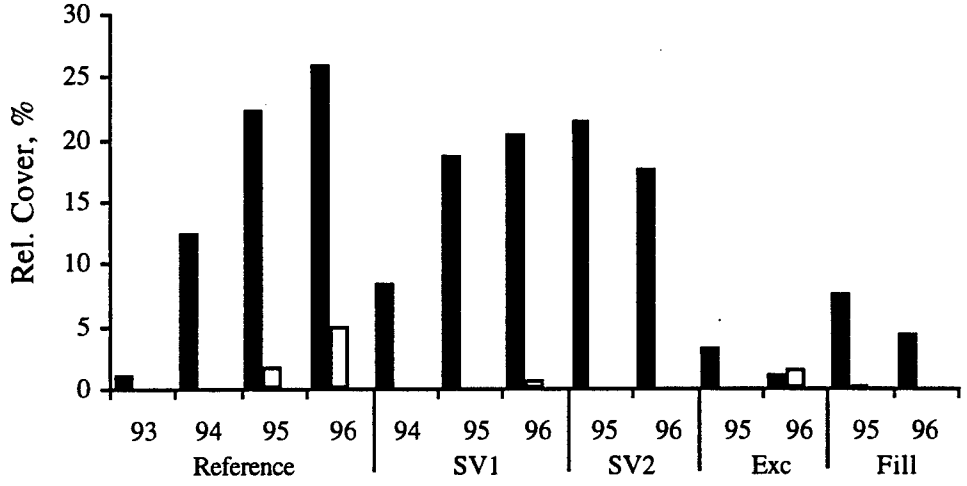
Eremocarpus setigerus



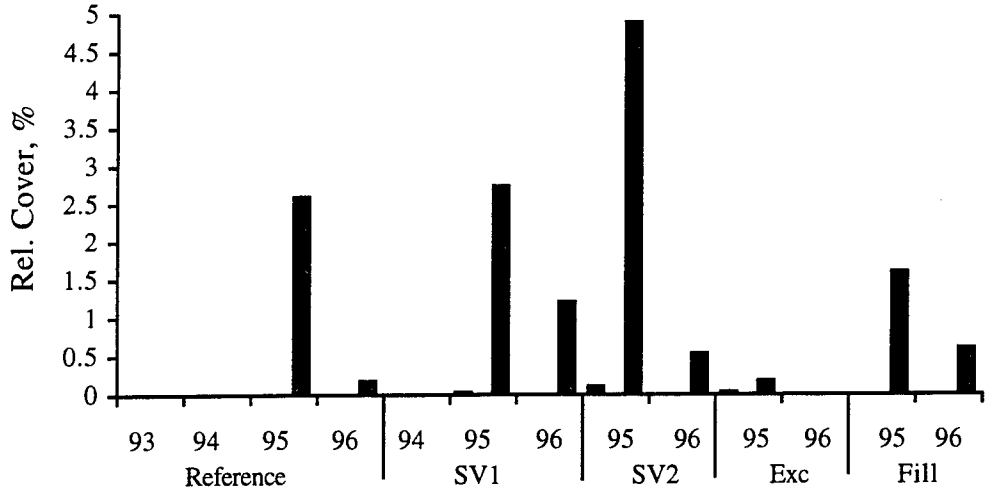
Erodium botrys



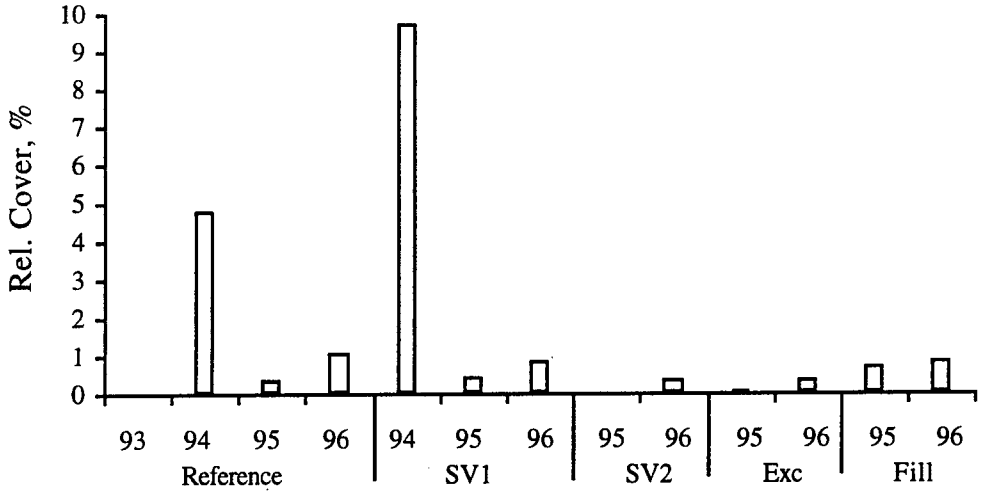
Eryngium aristulatum var. aristulatum



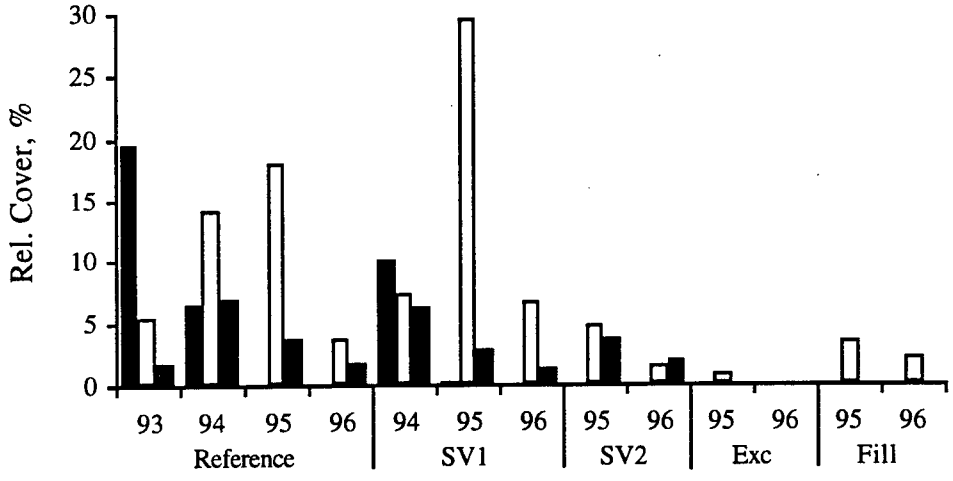
Hemizonia parryi



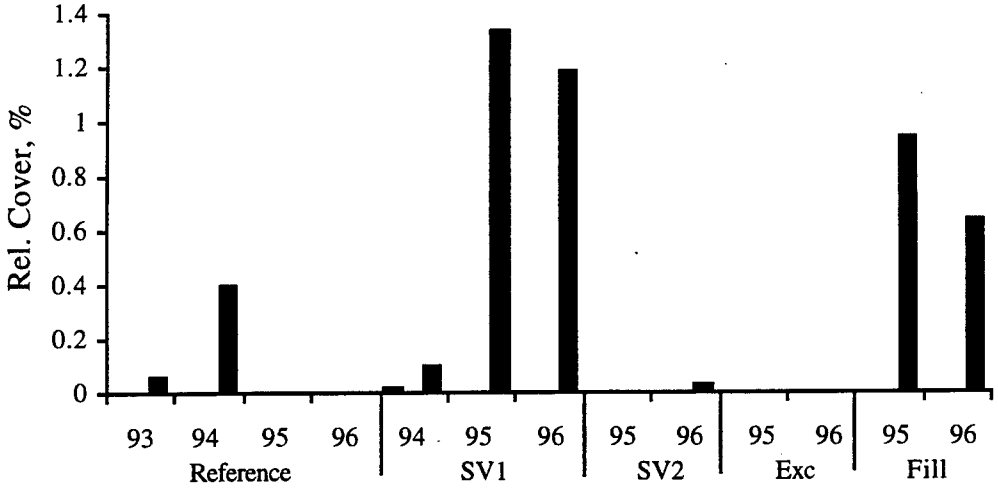
Hemizonia pungens



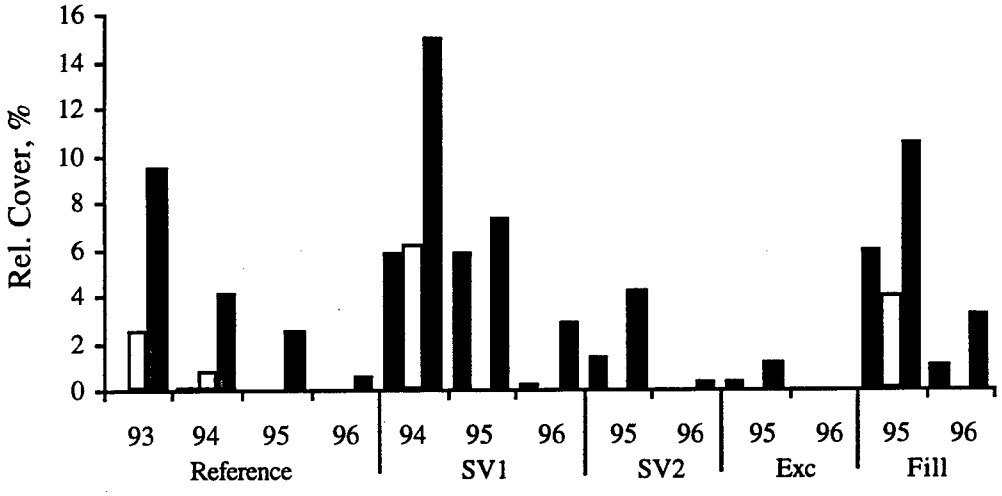
Hordeum marinum ssp. gussoneanum



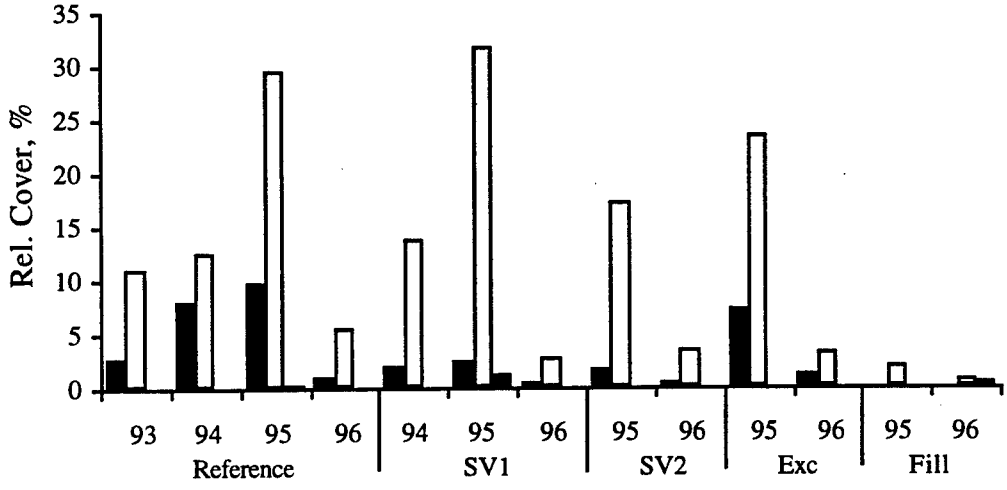
Hypochaeris glabra



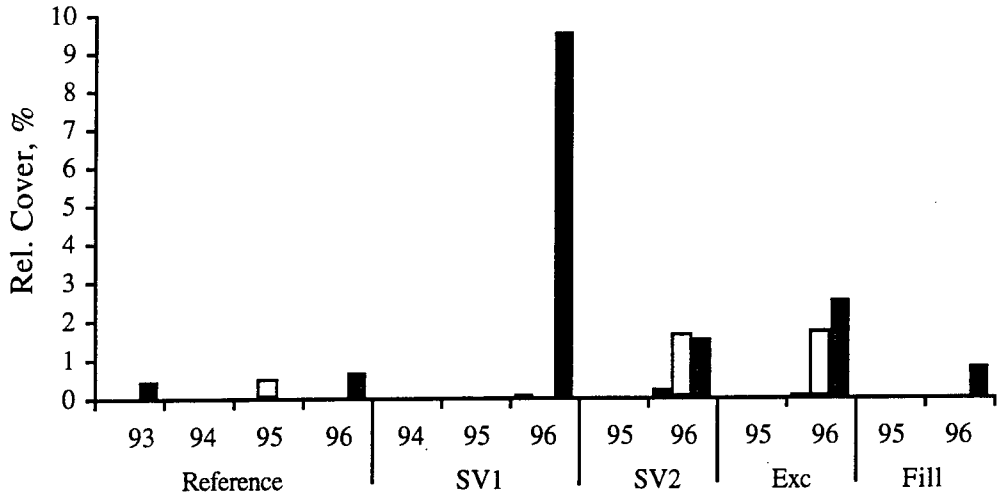
Juncus bufonius



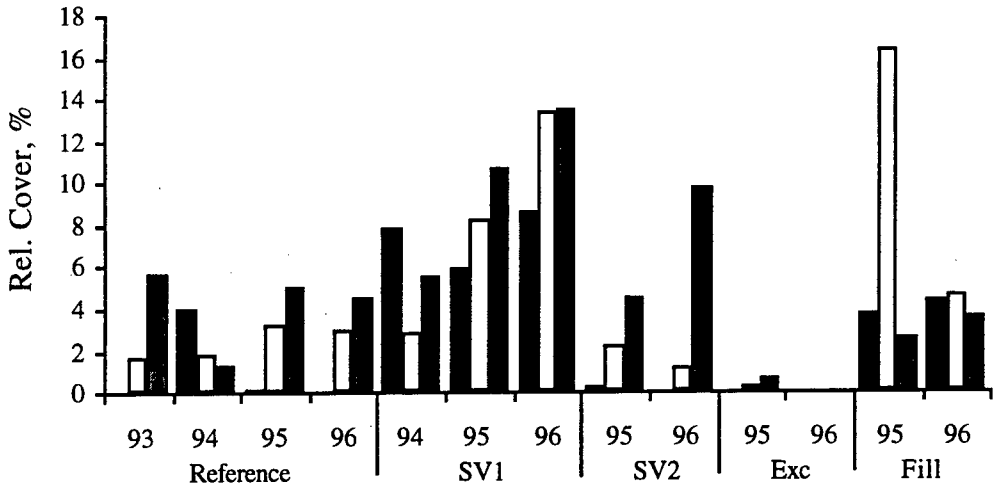
Lasthenia glaberrima



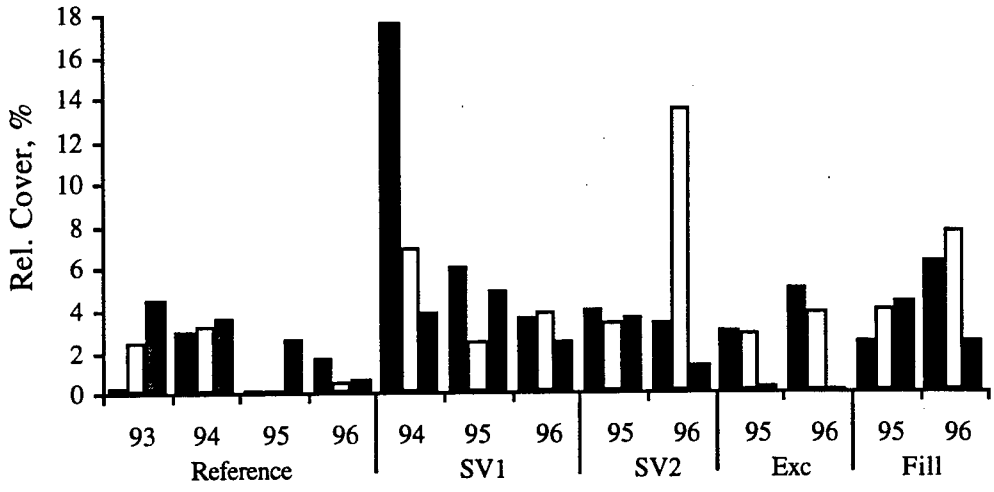
Lilaea scilloides



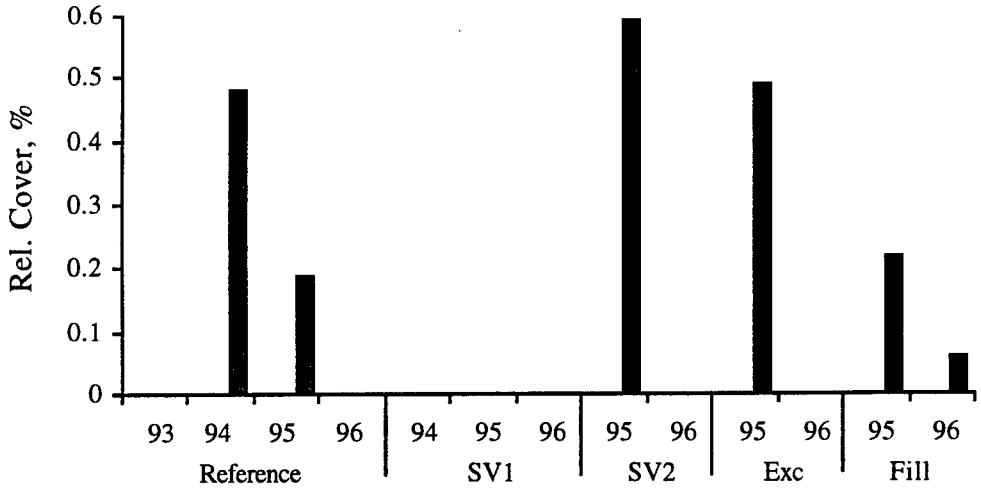
Lolium multiflorum



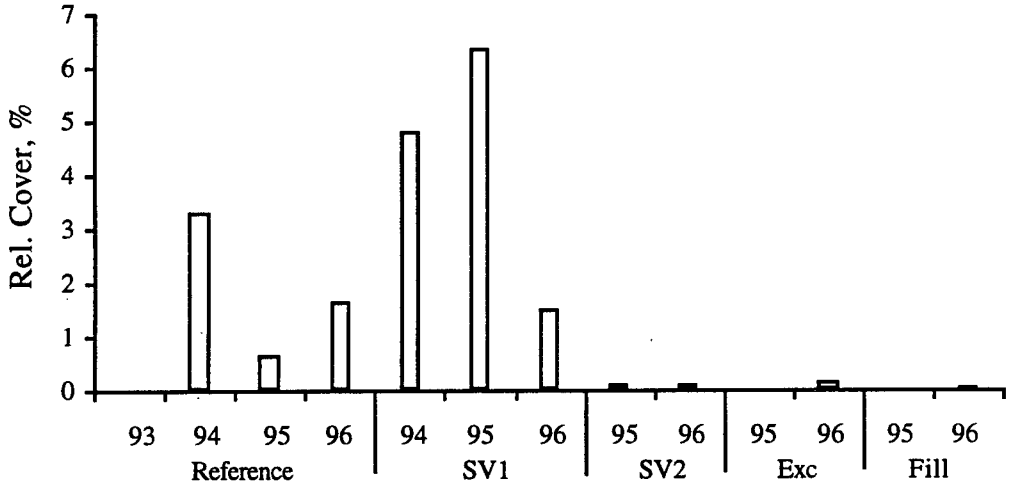
Lythrum hyssopifolium



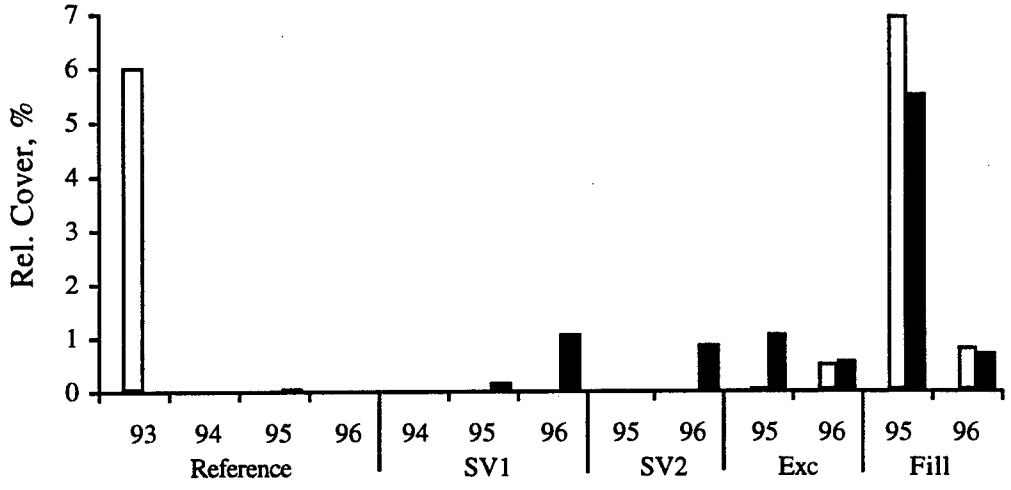
Navarretia intertexta ssp. intertexta



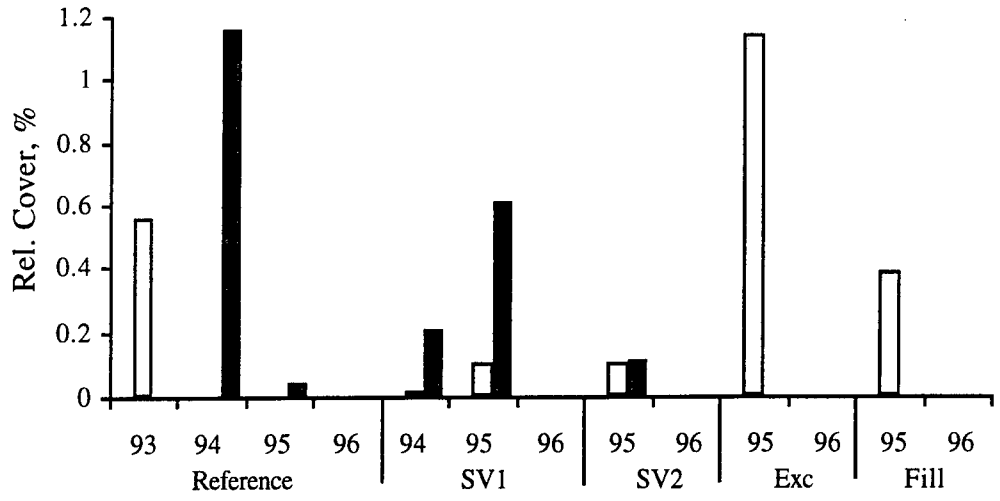
Picris echioides



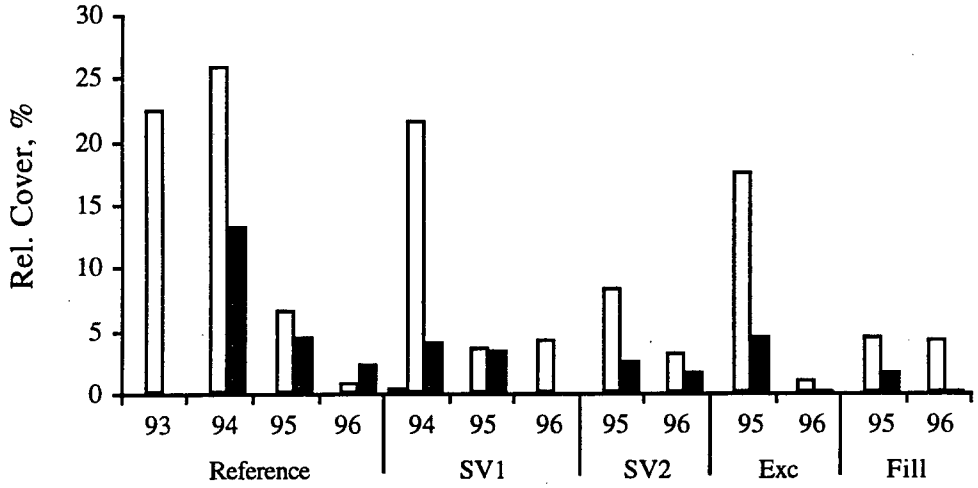
Pilularia americana



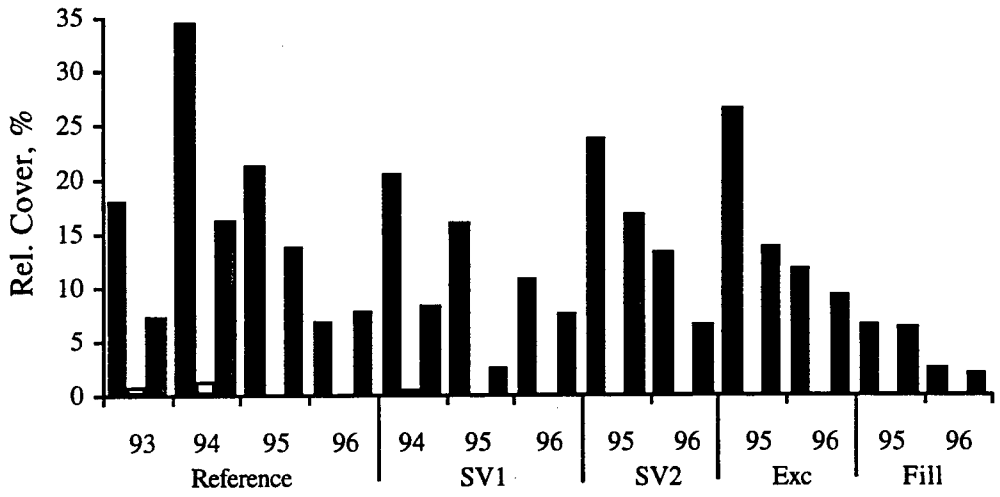
Plagiobothrys greenei



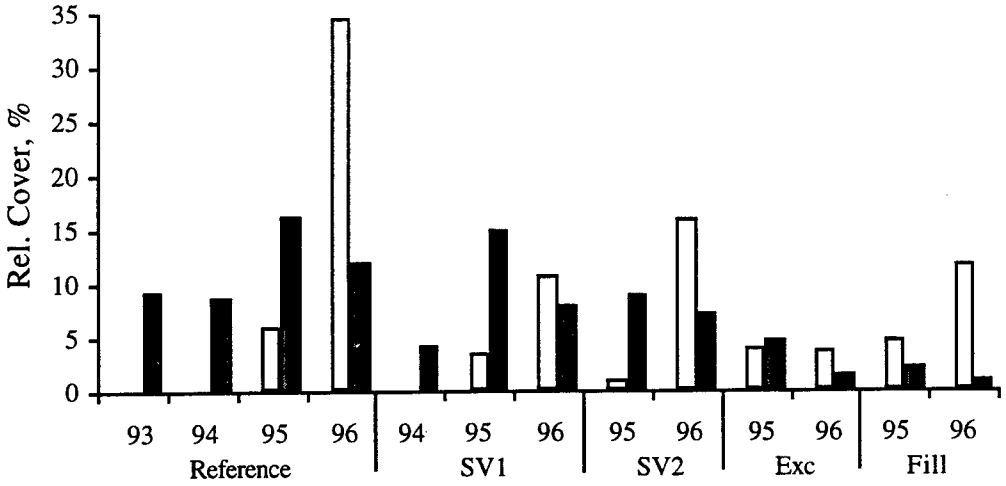
Plagiobothrys stipitatus var. micranthus



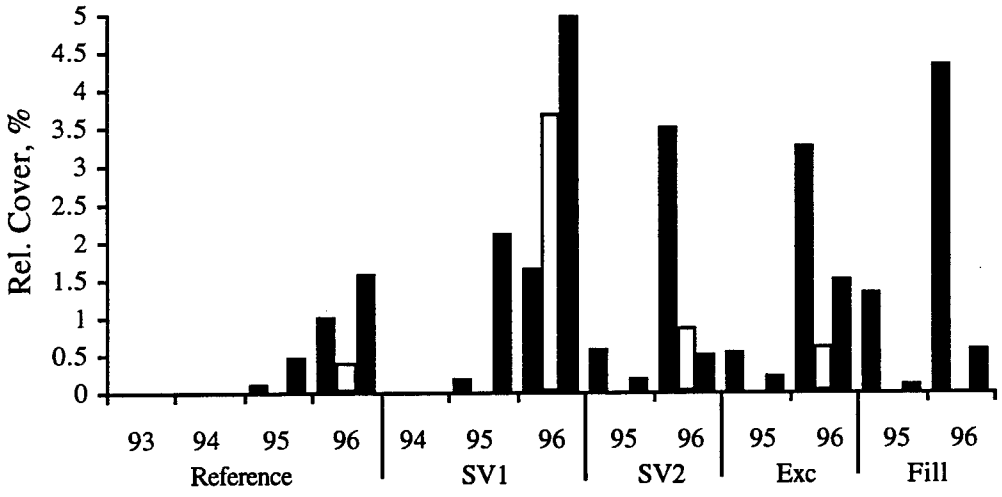
Plagiobothrys trachycarpus



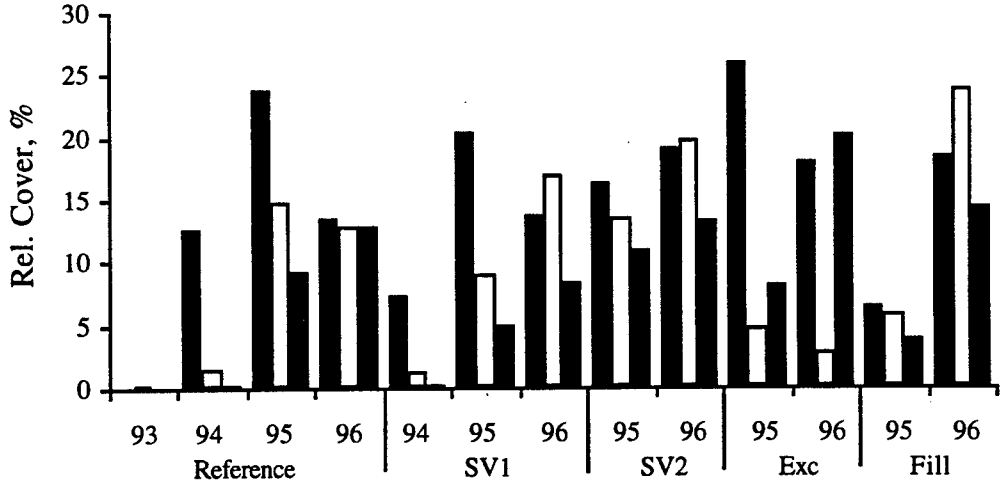
Pleuropogon californicus



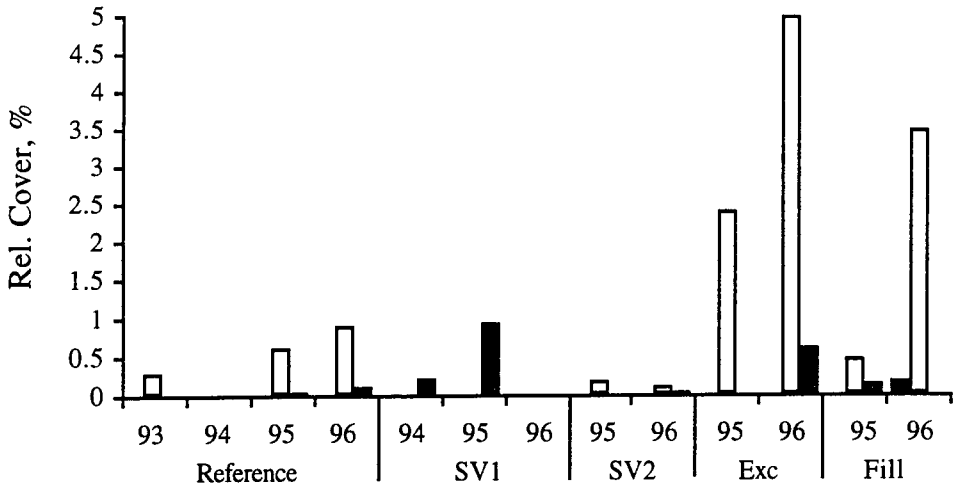
Polygonum arenastrum



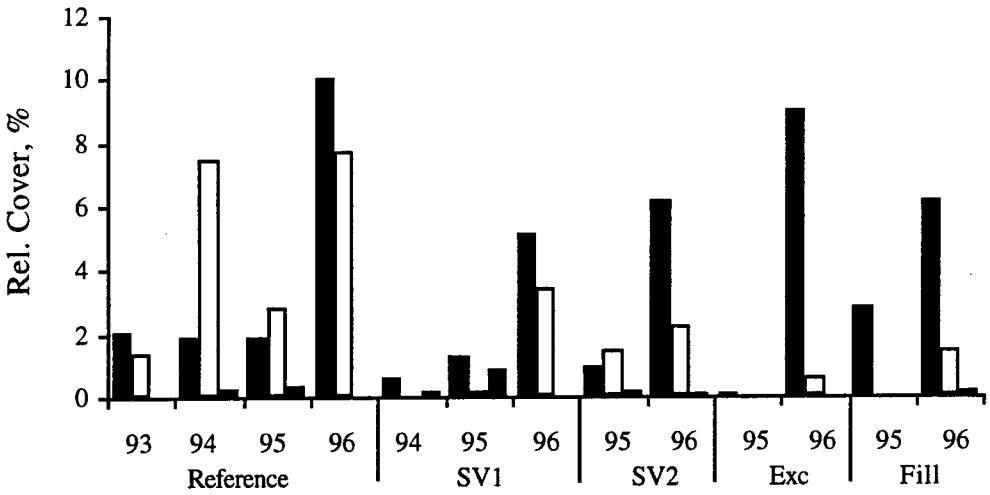
Polypogon monspeliensis



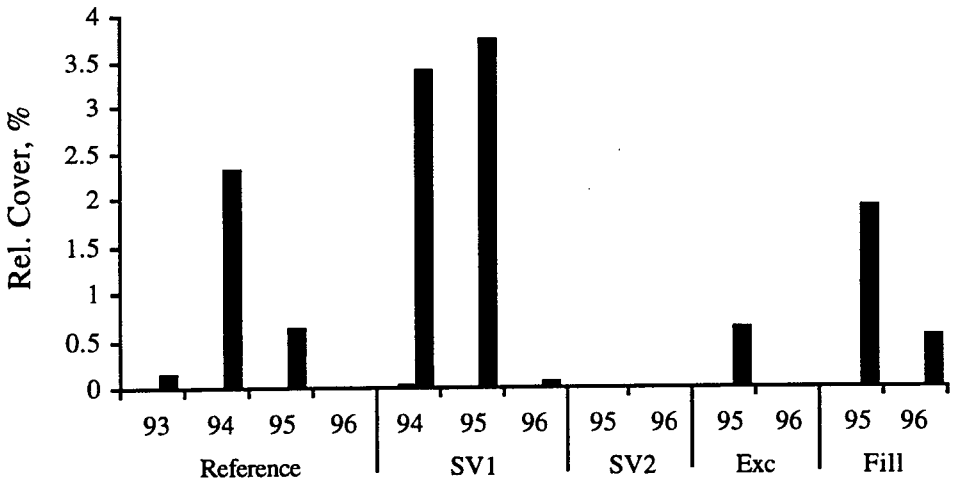
Psilocarphus brevissiumus var. multiflorus



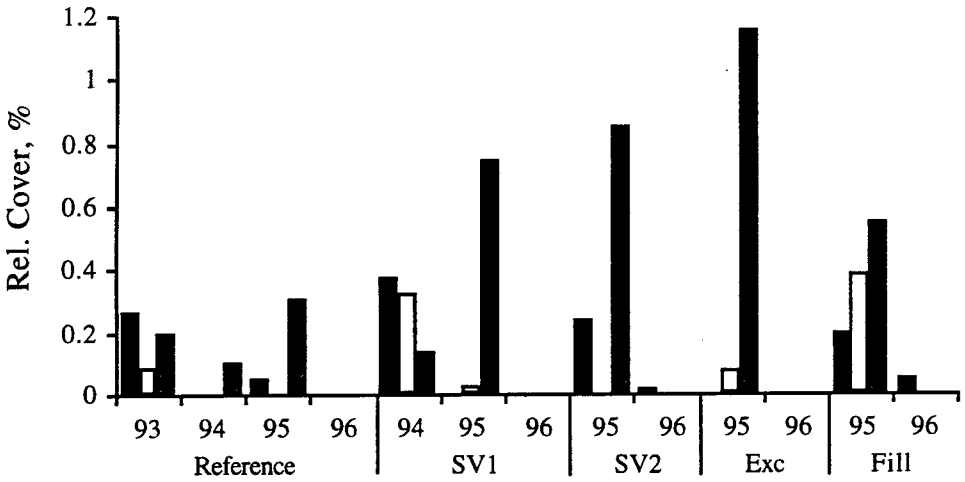
Rumex crispus



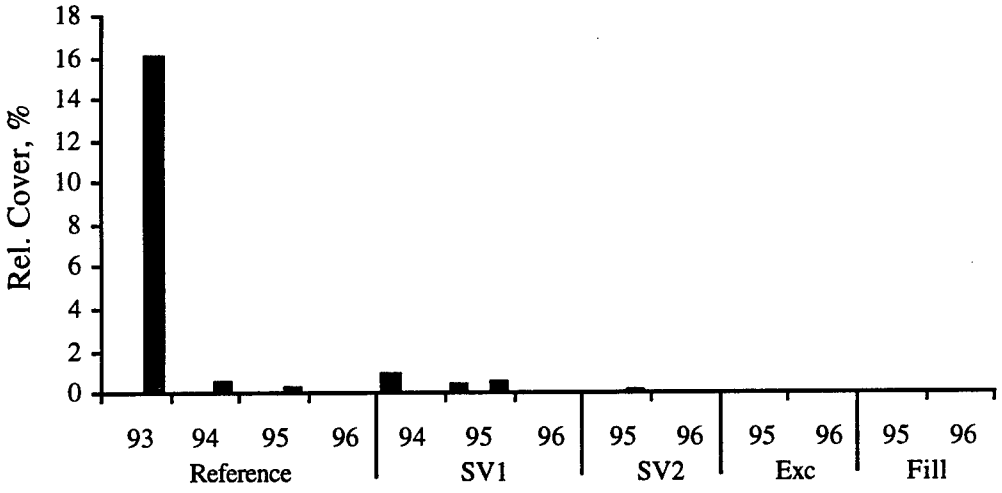
Spergula arvensis ssp. arvensis



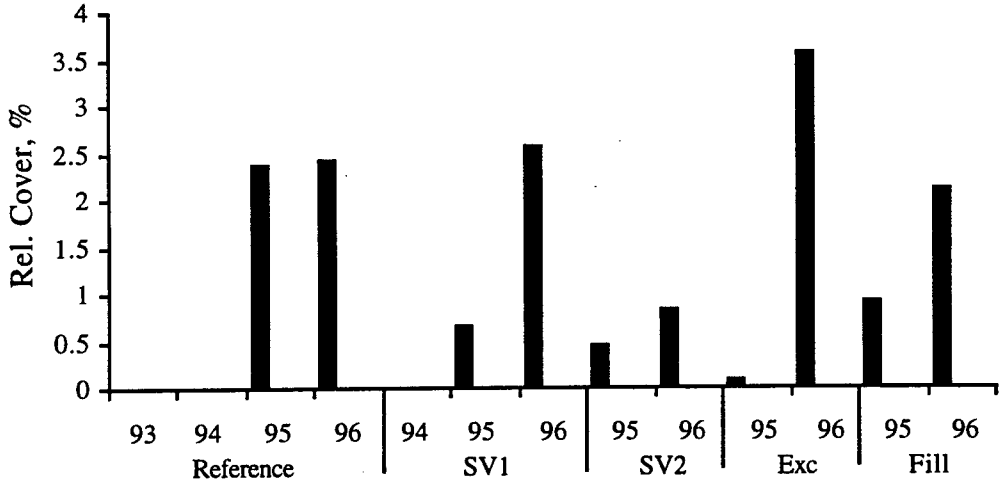
Veronica peregrina ssp. xalapensis



Vulpia bromoides



Xanthium strumarium



Appendix D-

Supporting Data on Invertebrate Animals

TABLE D1-QUANTITATIVE DATA ON INVERTEBRATES

Table D1.1. Average annual numbers of invertebrates per m of net tow, years 1 and 2.

SYSTEM	YEAR	POOL	YRS SINCE INOC.	TREATMENT	flatworm	nematode	gastropod	aphanoneurid worm	oligochaete	tardigrade	calanoid copepod	cyclopoid copepod	harpacticoid copepod	chydorid cladoceran
A	1(93-94)	TR5	na	Source	31.02		0.02	0.08			4	514	35	
		A3	na	Control							2.72	27.1		
		A1	1	Vac1							337	1.61		0.03
		A2	na	Vac2(Uninoc)							362	0.59		
		A4	na	Blocks(Uninoc.)							0.53	52.2		
		A5	na	Soil(Uninoc.)							0.06	483		
	2(94-95)	TR5	na	Source	0.62		0.13	0.46	0.05	0.01	12.3	29.4	25.5	7.45
		A3	na	Control	1.5				0.01		425	20.7		0.4
		A1	2	Vac1	0.07	0.01			0.01	0.07	157	0.71		0.16
		A2	1	Vac2	0.12						147	0.48		0.51
		A4	1	Blocks	0.07						100	4.58		0.55
		A5	1	Soil	0.04	0.06					35.7	43.9	0.02	3.81
B	1(93-94)	TR17	na	Source	0.25							4.36		
		B3	na	Control							0.03	79.9		
		B4	1	Vac1								10.2		0.18
		B2	na	Vac2(Uninoc.)	0.03			0.03				39.1		
		B1	na	Blocks(Uninoc.)								37.2		
		B5	na	Soil(Uninoc.)	0.03			0.03				37.8		
	2(94-95)	TR17	na	Source	0.76	2.12	0.02	5.94	0.03		0.29	36.4		225.1
		B3	na	Control	0.02						0.83	43.2		1.77
		B4	2	Vac1	0.15						0.06	16.6	0.01	120.7
		B2	1	Vac2	0.57		0.01				0.04	31.6		40.4
		B1	1	Blocks	0.07	0.06					0.22	25.7		9.63
		B5	1	Soil	0.18						0.54	9.83		99.5
C	1(93-94)	TR1	na	Source	6.84			0.17			0.06	161	1.04	0.17
		TR2	na	Source	5.87			0.06				150	0.1	
		TR3	na	Source	3.81			2.83				95.7	29.9	
		TR4	na	Source	3.93			0.5				69.2	0.02	
		TR1-4	na	TotalSource	20.45			3.56			0.06	475	31.1	0.17
		C1	na	Control								199		
		C3	1	Vac1	0.25						0.03	17.9		
		C2	na	Vac2(Uninoc.)				0.03				66.4		
		C5	na	Blocks(Uninoc.)								68.7		
		C4	na	Soil(Uninoc.)	0.03							191		
	2(94-95)	TR1	na	Source	0.67	16.8		40.6	3.16		0.01	90.3	3.58	98.66
		TR2	na	Source	3.15	0.18		1.37	0.06			171	2.12	0.03
		TR3	na	Source	2.52	2.94	0.04	8.43	0.01			98.9	5.02	48.99
		TR4	na	Source	6.08	0.4		3.28	0.06		0.01	33.3	0.34	1.06
		TR1-4	na	TotalSource	12.42	20.3	0.04	53.7	3.29		0.02	394	11.1	148.7
		C1	na	Control	0.04	0.02						35.1		2.49
		C3	2	Vac1	0.18			0.01			0.33	19.1		0.32
		C2	1	Vac2	0.06	0.01		0.01	0.01		0.04	40.1	0.01	1.81
		C5	1	Blocks	0.22		0.01	0.01			2.08	28.1		0.46
		C4	1	Soil	0.47	0.44			0.01		0.19	70.4		3.34

Table D1.1, Year 1 and year 2 invertebrates, continued

SYSTEM	YEAR	POOL	YRS SINCE INOC.	TREATMENT	daphniid cladoceran	macrothricid cladoceran	moinid cladoceran	conchostracan	ostracod	chironomid dipteran	culicid dipteran	tabanid dipteran	noctuid moth	collembolan	corixid hemipteran
A	1(93-94)	TR5	na	Source	4.37				210						
		A3	na	Control										0.38	
		A1	1	Vac1	17.86		0.02		2.7	0.58	0.03			0.23	0.08
		A2	na	Vac2(Uninoc)	0.08				0.63	0.58				0.1	
		A4	na	Blocks(Uninoc.)					0.69	0.49	0.03			0.98	
		A5	na	Soil(Uninoc.)	0.39		78.61		0.08	1				2.15	0.03
	2(94-95)	TR5	na	Source	12.8	0.01			7.57	8.36				7.71	0.45
		A3	na	Control	5.76		0.01		0.04	6.1				1.67	0.25
		A1	2	Vac1	25.36	0.05			2.02	0.62				0.31	
		A2	1	Vac2	8.17				1.04	0.36				0.46	0.06
		A4	1	Blocks	0.7	0.1	0.28		0.36	1.25				1.58	0.02
		A5	1	Soil	14.28	2.54	0.53		2.01	1.14				0.28	
B	1(93-94)	TR17	na	Source	4.24		0.86		2724	2.03	0.42				
		B3	na	Control			0.42		0.06	0.52				0.37	0.06
		B4	1	Vac1	12.61		177.1	0.08	56.2	0.65				0.92	0.53
		B2	na	Vac2(Uninoc.)			0.03		0.03	0.78				0.59	
		B1	na	Blocks(Uninoc.)	0.03		0.11			0.25				0.22	
		B5	na	Soil(Uninoc.)			0.16		0.12	0.33	0.03			0.06	0.12
	2(94-95)	TR17	na	Source	17.94	1.71	0.01		125	19.11	0.07	0.44	0.01	0.13	0.1
		B3	na	Control		0.22	53.28		0.81	7.79				0.9	0.06
		B4	2	Vac1	12.98	7.77	14		24	0.4				2.46	0.11
		B2	1	Vac2	2.78	0.3	10.54		22.5	2.53		0.01		1.57	0.02
		B1	1	Blocks	0.46	0.12	49.12		11.5	1.27				1.06	0.01
		B5	1	Soil	3.83	1.07	8.06		41.6	0.33		0.01		1.17	
C	1(93-94)	TR1	na	Source	2.49		0.87		0.17	0.1				3.97	
		TR2	na	Source					202	0.21				1.07	0.05
		TR3	na	Source	0.05		0.21		32.9	0.15				0.16	
		TR4	na	Source	8.1		0.24		551	0.98				0.32	0.08
		TR1-4	na	TotalSource	10.64		1.32		787	1.44				5.52	0.13
		C1	na	Control			264.5		0.11	0.4				1.38	
		C3	1	Vac1	0.35		229.3		10	0.6				0.18	0.14
		C2	na	Vac2(Uninoc.)	0.06		0.25		0.1	0.64				0.63	0.06
		C5	na	Blocks(Uninoc.)			265.3		1.03	0.37	0.03			4	0.05
		C4	na	Soil(Uninoc.)			0.9		0.33	0.38				0.35	0.01
	2(94-95)	TR1	na	Source	21.49	5.78	0.63		17.2	51.42	0.08	0.02		4.28	0.21
		TR2	na	Source	0.4				69.2	2.1		0.08		3.58	0.02
		TR3	na	Source		4.39			76.5	3.27				0.59	0.59
		TR4	na	Source	4.34	1.23	0.01		6.89	1.13	0.01	0.04		1.7	0.01
		TR1-4	na	TotalSource	26.23	11.4	0.64		170	57.92	0.09	0.14		10.15	0.83
		C1	na	Control		4.84	174.6		2.44	2.99				1.95	0.06
		C3	2	Vac1	0.02	3.04	101.6		11.8	0.88				1.27	0.06
		C2	1	Vac2	1.92	2.45	41.07		13.1	4.47				0.68	
		C5	1	Blocks		0.32	59.55		2.15	0.71				1.78	0.01
		C4	1	Soil	5.57	1.98	10.12		3.57	9.48				3.83	

Table D1.1, Year 1 and year 2 invertebrates, continued

SYSTEM	YEAR	POOL	YRS SINCE INOC.	TREATMENT	notonectid hemipteran	curculionid beetle	dytiscid beetle	haplipid beetle	hydrophilid beetle	staphylinid beetle	oribatid mite	water mite	TOTAL	#TAXA
A	1(93-94)	TR5	na	Source			1.14		0.08			10.3	811	11
		A3	na	Control									30.2	3
		A1	1	Vac1	0.06		0.11						360	12
		A2	na	Vac2(Uninoc)	0.06		0.07						364	8
		A4	na	Blocks(Uninoc.)	0.06		0.06						55.1	8
		A5	na	Soil(Uninoc.)			0.08						565	9
	2(94-95)	TR5	na	Source	0.06	0.04	0.2		0.26		5.95		119	20
		A3	na	Control									461	11
		A1	2	Vac1			0.05						187	13
		A2	1	Vac2			0.02						158	10
		A4	1	Blocks			0.01		0.02				109	13
		A5	1	Soil	0.01		0.02				0.01		104	15
B	1(93-94)	TR17	na	Source			0.35		0.06				2737	9
		B3	na	Control	0.11							0.03	81.5	9
		B4	1	Vac1			0.67						259	10
		B2	na	Vac2(Uninoc.)	0.06								40.6	8
		B1	na	Blocks(Uninoc.)	0.05								37.8	6
		B5	na	Soil(Uninoc.)	0.02		0.03						38.7	11
	2(94-95)	TR17	na	Source			0.32		0.49	0.01	0.13	0.19	436	23
		B3	na	Control	0.04						0.01		109	12
		B4	2	Vac1			0.05					0.01	199	14
		B2	1	Vac2			0.02				0.01		113	15
		B1	1	Blocks					0.01		0.01		99.3	14
		B5	1	Soil					0.02		0.01		166	13
C	1(93-94)	TR1	na	Source			0.47					1.18	178	13
		TR2	na	Source			0.43					0.03	360	10
		TR3	na	Source			0.27						166	10
		TR4	na	Source			0.53						635	11
		TR1-4	na	TotalSource			1.7					1.21	1339	14
		C1	na	Control	0.02		0.03						466	7
		C3	1	Vac1	0.06		0.1		0.05				259	12
		C2	na	Vac2(Uninoc.)	0.06		0.06						68.2	10
		C5	na	Blocks(Uninoc.)	0.07		0.03						340	9
		C4	na	Soil(Uninoc.)	0.14		0.01						193	9
	2(94-95)	TR1	na	Source			0.49	0.03	0.31		1.54	0.2	357	22
		TR2	na	Source			0.04		0.06		0.06	0.33	254	17
		TR3	na	Source			0.24	0.17	1.06		0.07	0.04	254	18
		TR4	na	Source			0.11		0.04	0.04	0.07	0.14	60.3	22
		TR1-4	na	TotalSource			0.88	0.2	1.47	0.04	1.74	0.71	926	24
		C1	na	Control								0.04	225	11
		C3	2	Vac1			0.01				0.07	0.02	139	15
		C2	1	Vac2			0.09					0.01	106	16
		C5	1	Blocks			0.01					0.02	95.5	14
		C4	1	Soil			0.03		0.02		0.07	0.07	110	16

Table D1.2. Average annual numbers of invertebrates per m of net tow, years 2 and 3. Year 2 is repeated from above so that numbers can be examined for the effect of treatments, seen in Vac2, Blocks, and Soil, all of which were started at the same time.

SYSTEM	YEAR	POOL	YRS SINCE INOC.	TREATMENT	flatworm	nematode	gastropod	aphanoneurid worm	oligochaete	tardigrade	calanoid copepod	cyclopoid copepod	harpacticoid copepod	chydorid cladoceran	daphniid cladoceran
A	2(94-95)	TR5	na	Source	0.62		0.13	0.46	0.05	0.01	12.33	29.36	25.5	7.45	12.8
		A3	na	Control	1.5				0.01		424.64	20.65		0.4	5.76
		A1	2	Vac1	0.07	0.01			0.01	0.07	157.29	0.71		0.16	25.4
		A2	1	Vac2	0.12						147.14	0.48		0.51	8.17
		A4	1	Blocks	0.07						99.96	4.58		0.55	0.7
		A5	1	Soil	0.04	0.06					35.7	43.86	0.02	3.81	14.3
	3(95-96)	TR5	na	Source	0.66	2.36	0.11	0.98	0.13		1.29	80.73	9.41	12.78	16
		A3	na	Control	0.02						162.35	10.19		1.16	1.95
		A1	3	Vac1	0.77	0.04				0.01	62.28	1.91		2.31	3.52
		A2	2	Vac2	1.07	0.02					98.8	1.38		1.42	2.8
		A4	2	Blocks	1.99	0.02					97.42	4.07		0.4	0.65
		A5	2	Soil	1.25	0.04					50.9	15.9	0.04	2.21	2.99
B	2(94-95)	TR17	na	Source	0.76	2.12	0.02	5.94	0.03		0.29	36.35		225.07	17.9
		B3	na	Control	0.02						0.83	43.17		1.77	
		B4	2	Vac1	0.15						0.06	16.6	0.01	120.72	13
		B2	1	Vac2	0.57		0.01				0.04	31.58		40.4	2.78
		B1	1	Blocks	0.07	0.06					0.22	25.69		9.63	0.46
		B5	1	Soil	0.18						0.54	9.83		99.5	3.83
	3(95-96)	TR17	na	Source		30.49	0.02	29.5	1.66		1.19	66.45		42.37	0.8
		B3	na	Control	0.07						3.94	28.06		1.69	0.05
		B4	3	Vac1	0.54	0.01					0.22	38.85		4.36	0.27
		B2	2	Vac2	0.23	0.02					0.64	33.98		6.91	0.36
		B1	2	Blocks	0.2						1.37	5.26		16.78	3.58
		B5	2	Soil	0.51						21.96	20.1	0.01	95.69	6.65
C	2(94-95)	TR1	na	Source	0.67	16.79		40.63	3.16		0.01	90.29	3.58	98.66	21.5
		TR2	na	Source	3.15	0.18		1.37	0.06			171.3	2.12	0.03	0.4
		TR3	na	Source	2.52	2.94	0.04	8.43	0.01			98.91	5.02	48.99	
		TR4	na	Source	6.08	0.4		3.28	0.06		0.01	33.3	0.34	1.06	4.34
		TR1-4	na	TotalSource	12.42	20.31	0.04	53.71	3.29		0.02	393.8	11.1	148.74	26.2
		C1	na	Control	0.04	0.02						35.12		2.49	
		C3	2	Vac1	0.18			0.01			0.33	19.09		0.32	0.02
		C2	1	Vac2	0.06	0.01		0.01	0.01		0.04	40.14	0.01	1.81	1.92
		C5	1	Blocks	0.22		0.01	0.01			2.08	28.1		0.46	
		C4	1	Soil	0.47	0.44			0.01		0.19	70.35		3.34	5.57
	3(95-96)	TR1	na	Source	2.19	3.7		9.67	0.16		0.01	111.3	4.26	50.5	36.2
		TR2	na	Source	2.1	2.66		1.29	0.02		0.47	515	6.16	2.14	
		TR3	na	Source	1.11	0.02		0.13				45.84	1.4	13.06	0.04
		TR4	na	Source	1.54	0.56	0.01	0.26			0.2	39.29	0.62	6.64	5.14
		TR1-4	na	TotalSource	6.94	6.94	0.01	11.35	0.18		0.68	711.4	12.4	72.34	41.4
		C1	na	Control	0.01						4.49	16.84		18.21	
		C3	3	Vac1	2.57						0.15	27.09		6.99	0.02
		C2	2	Vac2	0.17						0.01	22.2		7.07	
		C5	2	Blocks	0.36	0.1					74.8	19.78		0.73	1.27
		C4	2	Soil	0.4	0.09					0.86	39.31		15.03	0.98

Table D1.2, Year 2 and year 3 invertebrates, continued

SYSTEM	YEAR	POOL	YRS SINCE INOC.	TREATMENT	macrothricid cladoceran	moinid cladoceran	ostracod	baetid mayfly	libellulid odonatan	chironomid dipteran	culicid dipteran	dixid dipteran	tabanid dipteran	noctuid moth	collembolan
A	2(94-95)	TR5	na	Source	0.01		7.57			8.36					7.71
		A3	na	Control		0.01	0.04			6.1					1.67
		A1	2	Vac1	0.05		2.02			0.62					0.31
		A2	1	Vac2			1.04			0.36					0.46
		A4	1	Blocks	0.1	0.28	0.36			1.25					1.58
		A5	1	Soil	2.54	0.53	2.01			1.14					0.28
	3(95-96)	TR5	na	Source			3.54	0.01	0.01	26.06	0.14				0.16
		A3	na	Control		0.17	0.33			1.1					0.84
		A1	3	Vac1	0.01	0.84	1.07			0.47					0.04
		A2	2	Vac2	0.21		0.41			0.98					0.01
		A4	2	Blocks	0.09		0.8			0.77					0.01
		A5	2	Soil	0.52	0.15	0.4		0.04	1.6			0.03		0.04
B	2(94-95)	TR17	na	Source	1.71	0.01	125			19.11	0.07		0.44	0.01	0.13
		B3	na	Control	0.22	53.28	0.81			7.79					0.9
		B4	2	Vac1	7.77	14	24			0.4					2.46
		B2	1	Vac2	0.3	10.54	22.5			2.53			0.01		1.57
		B1	1	Blocks	0.12	49.12	11.5			1.27					1.06
		B5	1	Soil	1.07	8.06	41.6			0.33			0.01		1.17
	3(95-96)	TR17	na	Source	0.1	18.11	19	0.03	0.03	36.72	0.78	0.01		0.13	0.16
		B3	na	Control	0.1	11.32	5.38			0.85					0.04
		B4	3	Vac1	0.09	0.02	0.49			0.3				0.01	0.01
		B2	2	Vac2	0.17	3.07	1.56			0.81					0.27
		B1	2	Blocks	0.28	0.11	2.09			2.33					0.17
		B5	2	Soil	0.22	0.37	1.88			4.86			0.14		0.1
C	2(94-95)	TR1	na	Source	5.78	0.63	17.2			51.42	0.08		0.02		4.28
		TR2	na	Source			69.2			2.1			0.08		3.58
		TR3	na	Source	4.39		76.5			3.27					0.59
		TR4	na	Source	1.23	0.01	6.89			1.13	0.01		0.04		1.7
		TR1-4	na	TotalSource	11.4	0.64	170			57.92	0.09		0.14		10.2
		C1	na	Control	4.84	174.6	2.44			2.99					1.95
		C3	2	Vac1	3.04	101.6	11.8			0.88					1.27
		C2	1	Vac2	2.45	41.07	13.1			4.47					0.68
		C5	1	Blocks	0.32	59.55	2.15			0.71					1.78
		C4	1	Soil	1.98	10.12	3.57			9.48					3.83
	3(95-96)	TR1	na	Source	1.13	0.68	8.23		0.02	40.72	0.26	0.01	0.01		0.08
		TR2	na	Source			84.3			37.15	3.52		0.61		0.1
		TR3	na	Source	7.7		15.6			13.96	0.12		0.05		0.08
		TR4	na	Source	0.4	0.06	60.4			9.75	0.17		0.14	0.03	0.08
		TR1-4	na	TotalSource	9.23	0.74	169		0.02	101.6	4.07	0.01	0.81	0.03	0.34
		C1	na	Control	0.07	20.98	6.51			1.09					0.02
		C3	3	Vac1	0.98	20.16	3.81			0.91					0.01
		C2	2	Vac2	0.26	1.93	5.43			1.74			0.01		0.14
		C5	2	Blocks	2.1	83.56	1.06			0.93					0.01
		C4	2	Soil	0.42	6.58	1.16			4.68	0.01				0.04

Table D1.2, Year 2 and year 3 invertebrates, continued

SYSTEM	YEAR	POOL	YRS SINCE INOC.	TREATMENT	corixid hemipteran	notonectid hemipteran	curculionid beetle	dytiscid beetle	haliplid beetle	hydrophilid beetle	staphylinid beetle	oribatid mite	water mite	TOTAL	# TAXA
A	2(94-95)	TR5	na	Source	0.45	0.06	0.04	0.2		0.26		5.95		119	20
		A3	na	Control	0.25									461	11
		A1	2	Vac1				0.05						187	13
		A2	1	Vac2	0.06			0.02						158	10
		A4	1	Blocks	0.02			0.01		0.02				109	13
		A5	1	Soil		0.01		0.02				0.01		104	15
	3(95-96)	TR5	na	Source	1.44	0.09		0.41	0.01	0.44		8.33		165	22
		A3	na	Control	0.02	0.44		0.02		0.11				179	13
		A1	3	Vac1		0.01								73	13
		A2	2	Vac2	0.12	0.04		0.02						107	13
		A4	2	Blocks	0.09	0.04				0.04			0.01	106	14
		A5	2	Soil	0.07	0.09		0.02		0.01		0.03	0.07	76	20
B	2(94-95)	TR17	na	Source	0.1			0.32		0.49	0.01	0.13	0.19	436	23
		B3	na	Control	0.06	0.04						0.01		109	12
		B4	2	Vac1	0.11			0.05					0.01	199	14
		B2	1	Vac2	0.02			0.02				0.01		113	15
		B1	1	Blocks	0.01					0.01		0.01		99	14
		B5	1	Soil						0.02		0.01		166	13
	3(95-96)	TR17	na	Source	1.49	0.01		0.45	0.01	0.55		1.34		251	24
		B3	na	Control	0.09	0.06						0.04	0.05	52	14
		B4	3	Vac1	0.05	0.04		0.01		0.01		0.01	0.01	45	18
		B2	2	Vac2	0.04	0.1		0.01				0.01	0.03	48	16
		B1	2	Blocks	0.01	0.04		0.01		0.04				32	14
		B5	2	Soil	0.3	0.02		0.1		0.01		0.06		153	17
C	2(94-95)	TR1	na	Source	0.21			0.49	0.03	0.31		1.54	0.2	357	22
		TR2	na	Source	0.02			0.04		0.06		0.06	0.33	254	17
		TR3	na	Source	0.59			0.24	0.17	1.06		0.07	0.04	254	18
		TR4	na	Source	0.01			0.11		0.04	0.04	0.07	0.14	60	22
		TR1-4	na	TotalSource	0.83			0.88	0.2	1.47	0.04	1.74	0.71	926	24
		C1	na	Control	0.06								0.04	225	11
		C3	2	Vac1	0.06			0.01				0.07	0.02	139	15
		C2	1	Vac2				0.09					0.01	106	16
		C5	1	Blocks	0.01			0.01					0.02	95	14
		C4	1	Soil				0.03		0.02		0.07	0.07	110	16
	3(95-96)	TR1	na	Source	0.83	0.11		0.31		0.84		4.4	0.03	276	24
		TR2	na	Source	0.48	0.03		0.56		0.23	0.02	1.42	0.47	659	20
		TR3	na	Source	0.43	0.13		0.14		0.32		1.07	0.02	101	19
		TR4	na	Source	0.27	0.01		0.15		0.12		0.62	0.28	127	23
		TR1-4	na	TotalSource	2.01	0.28		1.16		1.51	0.02	7.51	0.8	1162	27
		C1	na	Control	0.04	0.15							0.01	68	12
		C3	3	Vac1	0.02	0.04							0.01	63	13
		C2	2	Vac2	0.04	0.05		0.01				0.02	0.06	39	15
		C5	2	Blocks	0.02					0.02				185	13
		C4	2	Soil	0.07	0.12		0.06		0.03		0.02	0.01	70	18

TABLE D2-DATES COPEPODS WERE PRESENT IN REPRESENTATIVE SUBSAMPLES

This set of tables gives results of Dr. Janet W. Reid's tally of copepods by date in representative subsamples we sent her. All data are from year 2 (1994-95). In the tables, "1" indicates samples with juveniles only, "2" samples with adults present (with or without juveniles).

The calanoid *Hesperodiaptomus eiseni* (Lilljeborg, 1889)

System	Pool	Trtm	17-Dec	29-Dec	16-Jan	30-Jan	13-Feb	25-Feb	11-Mar	26-Mar	8-Apr	21-Apr	7-May
A	TR5	Src			2	2	2	2		2			
	A3	Con	1	2	2	2	2			2			
	A1	Vac1	2	2	2	2	2	2		2	2	2	2
	A2	Vac2	2	2	2	2	2	2	2	2	2	2	2
	A4	Blocks	1	2	2	2	2	2		2	2	2	2
	A5	Soil	1	2	2	2	2	2		2	2		
B	TR17	Src			2			1					
	B3	Con		2			2	2			2	2	
	B4	Vac1		2								2	
	B2	Vac2									2		2
	B1	Blocks		2		2	1	2		2	2	2	
	B5	Soil		1				2		2	2	2	
C	TR1	Src											
	TR2	Src											
	TR3	Src	1										
	TR4	Src			2								
	C1	Con											
	C3	Vac1	2	2	2		2	2			2	2	
	C2	Vac2											
	C5	Blocks											
	C4	Soil								2			

The calanoid *Leptodiaptomus tyrrelli* (Poppe, 1888)

System	Pool	Trtm	17-Dec	29-Dec	16-Jan	30-Jan	13-Feb	25-Feb	11-Mar	26-Mar	8-Apr	21-Apr	7-May
A	TR5	Src		1							1		
	A3	Con	1		2		2		2	2	2		
	A1	Vac1		1	2		2	2	2		2	2	2
	A2	Vac2	2	2	2		2	2	2	2	2	2	2
	A4	Blocks	1	2	2		2	2		2	2	2	2
	A5	Soil		1			2	2		2	2		
B	TR17	Src											
	B3	Con											
	B4	Vac1											
	B2	Vac2											
	B1	Blocks			2								
	B5	Soil						2		2	2	2	2
C	TR1	Src											
	TR2	Src											
	TR3	Src											
	TR4	Src											
	C1	Con										1	2
	C3	Vac1		2									
	C2	Vac2		2									
	C5	Blocks		1				2		2	2	2	4
	C4	Soil		2									

The cyclopoid *Acanthocyclops carolinianus* (Yeatman, 1944)

System	Pool	Trtm	17-Dec	29-Dec	16-Jan	30-Jan	13-Feb	25-Feb	11-Mar	26-Mar	8-Apr	21-Apr	7-May
A	TR5	Src		2		2	2	2	2	2	2		
	A3	Con	2	2			2		1	1	2		
	A1	Vac1	2					2		1	1		
	A2	Vac2		2						1	2	2	2
	A4	Blocks	2	2			1		2	1			
	A5	Soil	2	2	2		2	2	2	1	2		
B	TR17	Src	2			1	2	2	2	2	2		
	B3	Con	2	2	2			2	2	1	2	1	1
	B4	Vac1	2	2	2	2	2	2	1	1	2		
	B2	Vac2	2	2	2	2	2				1		
	B1	Blocks	2	2	2	2		2	2				
	B5	Soil			2			2	2	2	2		1
C	TR1	Src	2	2	2	2	2	2	2	2	2		
	TR2	Src	2	2		2	2		2	2			
	TR3	Src				2		2	2	2	2		
	TR4	Src		2		2		2	2	2			
	C1	Con	2		2			2	1	2	2	2	1
	C3	Vac1	2	2		2		2					
	C2	Vac2	2	2	2		1	2					
	C5	Blocks	2	2	2	2		2	2	1			
	C4	Soil	2	2	2	2	2	2	2	2	2	1	

The cyclopoid *Diacyclops crassicaudis brachycercus* (Kiefer, 1929)

System	Pool	Trtm	17-Dec	29-Dec	16-Jan	30-Jan	13-Feb	25-Feb	11-Mar	26-Mar	8-Apr	21-Apr	7-May
A	TR5	Src											
	A3	Con	2										
	A1	Vac1											
	A2	Vac2											
	A4	Blocks											
	A5	Soil											
B	TR17	Src											
	B3	Con	2										
	B4	Vac1	2						1				
	B2	Vac2											
	B1	Blocks											
	B5	Soil	2										
C	TR1	Src											
	TR2	Src											
	TR3	Src											
	TR4	Src											
	C1	Con							2	1			
	C3	Vac1	1						1				
	C2	Vac2											
	C5	Blocks											
	C4	Soil											

The cyclopoid *Diacyclops lubbocki* (Brady, 1868)

System	Pool	Trtm	17-Dec	29-Dec	16-Jan	30-Jan	13-Feb	25-Feb	11-Mar	26-Mar	8-Apr	21-Apr	7-May
A	TR5	Src	2	2	2	2	2	2					
	A3	Con		2						1			
	A1	Vac1							2	1		1	1
	A2	Vac2											
	A4	Blocks						2	2			1	
	A5	Soil	2	2	2			2	2	1	1		
B	TR17	Src	2	2	2		2	2					
	B3	Con		2	2	2	2	2		1		2	
	B4	Vac1		2	2	2	2	2	1	1	1	2	
	B2	Vac2			2	2	2	2	1	1		1	1
	B1	Blocks		2	2	2	2	2		2	2	1	1
	B5	Soil	1	2		2	2	2	1		1	1	1
C	TR1	Src	2	2	2		2	2	1	2			
	TR2	Src	2	2	2	2	2		2	1			
	TR3	Src	2	2	2	2	2	2		1			
	TR4	Src	2	2	2	2	2	2		2			
	C1	Con	2	2	2	2	2	2		1		2	1
	C3	Vac1	2		2	2	2	2	2	1	2	1	
	C2	Vac2	2	2	2	2	2	2	2	1	2	1	
	C5	Blocks			2	2	2	2	2		2	2	
	C4	Soil			2	2	2	2	2	2	2		

The harpacticoid *Attheyella* (*Mrazekiella*) *dogieli* (Rylov, 1923)

System	Pool	Trtm	17-Dec	29-Dec	16-Jan	30-Jan	13-Feb	25-Feb	11-Mar	26-Mar	8-Apr	21-Apr	7-May
A	TR5	Src	2	2	2	2	2	2	2	2	2		
	A3	Con											
	A1	Vac1											
	A2	Vac2											
	A4	Blocks											
	A5	Soil									2		
B	TR17	Src											
	B3	Con											
	B4	Vac1											
	B2	Vac2											
	B1	Blocks											
	B5	Soil											
C	TR1	Src				2	2	2	2	2			
	TR2	Src				2			2	2			
	TR3	Src	2	2	2	2			2	2	2		
	TR4	Src					2		2	2			
	C1	Con											
	C3	Vac1											
	C2	Vac2											
	C5	Blocks											
	C4	Soil											

TABLE D3-DATES CLADOCERANS WERE PRESENT IN REPRESENTATIVE SUBSAMPLES

This set of tables gives results of Dr. Brenda Hann's tally of cladocerans by date in representative subsamples we sent her. For simplicity, dates of 1994-95 have been used for both years-these differed by no more than two days in 1995-96. Also present: A possible third species of *Alona* present only in pool C5, 26 Mar 95 and *Ceriodaphnia sp.* present only in TR5 on 26 Apr 1996. For each species, "Sys/Yr" indicates the pool system (A, B, or C) and year. Year 2=1994-95; year 3=1995-96.

The chydorid *Alona* cf. *circumfimbriata*

Sys/Yr	Pool	Trtm	17-Dec	29-Dec	16-Jan	30-Jan	13-Feb	25-Feb	11-Mar	26-Mar	8-Apr	21-Apr	7-May
A/2	TR5	Src					+						
	A3	Con											
	A1	Vac1											
	A2	Vac2											
	A4	Blocks											
	A5	Soil			+								
B/2	TR17	Src			+		+	+	+				
	B3	Con								+			
	B4	Vac1											
	B2	Vac2				+		+	+				
	B1	Blocks			+		+	+	+				
	B5	Soil					+	+	+				
C/2	TR1	Src			+								
	TR2	Src			+								
	TR3	Src											
	TR4	Src											
	C1	Con						+	+	+			
	C3	Vac1				+	+						
	C2	Vac2				+	+						
	C5	Blocks				+							
	C4	Soil					+						

Sys/Yr	Pool	Trtm	17-Dec	29-Dec	16-Jan	30-Jan	13-Feb	25-Feb	11-Mar	26-Mar	8-Apr	21-Apr	7-May
A/3	TR5	Src							+				
	A3	Con			+								
	A1	Vac1					+						
	A2	Vac2			+								
	A4	Blocks											
	A5	Soil			+								
B/3	TR17	Src					+		+				
	B3	Con			+								
	B4	Vac1			+								
	B2	Vac2			+		+			+			
	B1	Blocks			+								
	B5	Soil					+	+					
C/3	TR1	Src				+	+						
	TR2	Src					+	+					
	TR3	Src											
	TR4	Src											
	C1	Con		+	+	+	+	+					
	C3	Vac1			+	+	+	+					
	C2	Vac2		+	+	+	+	+					
	C5	Blocks						+					
	C4	Soil					+		+				

The chydorid *Alona* cf. *setulosa*

Sys/Yr	Pool	Trtm	17-Dec	29-Dec	16-Jan	30-Jan	13-Feb	25-Feb	11-Mar	26-Mar	8-Apr	21-Apr	7-May
A/2	TR5	Src		+	+			+	+				
	A3	Con								+			
	A1	Vac1								+			
	A2	Vac2								+	+		
	A4	Blocks		+									
	A5	Soil		+				+	+				
B/2	TR17	Src		+	+			+	+	+			
	B3	Con				+				+	+	+	+
	B4	Vac1		+		+	+	+	+	+			
	B2	Vac2		+						+	+	+	
	B1	Blocks								+	+	+	+
	B5	Soil								+	+		+
C/2	TR1	Src											
	TR2	Src		+									
	TR3	Src											
	TR4	Src											
	C1	Con									+		
	C3	Vac1											
	C2	Vac2											
	C5	Blocks						+	+				
	C4	Soil								+	+	+	

Sys/Yr	Pool	Trtm	17-Dec	29-Dec	16-Jan	30-Jan	13-Feb	25-Feb	11-Mar	26-Mar	8-Apr	21-Apr	7-May
A/3	TR5	Src				+							
	A3	Con		+	+	+	+	+					
	A1	Vac1			+		+	+			+	+	
	A2	Vac2		+		+							
	A4	Blocks			+	+				+			
	A5	Soil			+	+	+	+		+			
B/3	TR17	Src								+			
	B3	Con			+			+			+		
	B4	Vac1			+	+	+	+	+				
	B2	Vac2					+	+	+	+		+	
	B1	Blocks			+	+	+	+		+	+		
	B5	Soil		+	+	+	+	+	+				
C/3	TR1	Src											
	TR2	Src							+				
	TR3	Src											
	TR4	Src											
	C1	Con						+	+	+	+		
	C3	Vac1							+				
	C2	Vac2							+	+		+	
	C5	Blocks					+	+	+				
	C4	Soil			+	+	+	+	+	+		+	

The chydorid *Chydorus* cf. *sphaericus*

Sys/Yr	Pool	Trtm	17-Dec	29-Dec	16-Jan	30-Jan	13-Feb	25-Feb	11-Mar	26-Mar	8-Apr	21-Apr	7-May
A/2	TR5	Src		+	+	+	+	+	+		+		
	A3	Con					+			+			
	A1	Vac1											
	A2	Vac2					+	+	+	+			
	A4	Blocks											
	A5	Soil		+			+	+	+				
B/2	TR17	Src		+	+	+	+	+	+	+			
	B3	Con					+				+		
	B4	Vac1				+	+	+	+	+	+	+	
	B2	Vac2						+	+		+	+	+
	B1	Blocks			+		+	+	+	+	+		
	B5	Soil				+	+	+	+	+	+	+	
C/2	TR1	Src				+	+	+	+	+	+		
	TR2	Src											
	TR3	Src			+	+	+	+	+	+	+		
	TR4	Src				+		+	+	+			
	C1	Con								+			
	C3	Vac1					+	+	+				
	C2	Vac2		+			+	+	+				
	C5	Blocks					+	+	+	+			
	C4	Soil				+	+	+	+				

Sys/Yr	Pool	Trtm	17-Dec	29-Dec	16-Jan	30-Jan	13-Feb	25-Feb	11-Mar	26-Mar	8-Apr	21-Apr	7-May
A/3	TR5	Src				+		+	+				
	A3	Con				+	+						
	A1	Vac1		+									
	A2	Vac2			+		+		+				
	A4	Blocks											
	A5	Soil					+	+	+	+			
B/3	TR17	Src					+	+		+			
	B3	Con					+		+		+		
	B4	Vac1					+	+		+	+		
	B2	Vac2			+					+	+		
	B1	Blocks					+		+	+			
	B5	Soil			+		+	+	+	+			
C/3	TR1	Src			+	+	+	+	+				
	TR2	Src									+		
	TR3	Src					+	+	+	+	+		
	TR4	Src					+	+	+				
	C1	Con							+	+			
	C3	Vac1								+			
	C2	Vac2						+	+	+	+		
	C5	Blocks											
	C4	Soil											

The daphniid *Simocephalus* cf. *acutirostris*

Sys/Yr	Pool	Trt.	17-Dec	29-Dec	16-Jan	30-Jan	13-Feb	25-Feb	11-Mar	26-Mar	8-Apr	21-Apr	7-May
A/2	TR5	Src	+	+	+	+	+	+	+	+	+		
	A3	Con			+		+				+		
	A1	Vac1		+	+	+	+	+	+	+	+	+	
	A2	Vac2		+	+	+	+	+	+	+	+	+	
	A4	Blks	+	+	+	+	+	+	+	+	+	+	
	A5	Soil			+	+	+	+	+	+	+		
B/2	TR17	Src	+	+	+	+	+	+	+	+	+		
	B3	Con											
	B4	Vac1		+	+	+	+	+	+	+	+	+	
	B2	Vac2				+	+	+	+	+	+	+	+
	B1	Blks				+	+	+	+	+	+	+	+
	B5	Soil				+	+			+	+	+	+
C/2	TR1	Src		+		+	+	+	+	+	+		
	TR2	Src											
	TR3	Src											
	TR4	Src	+			+		+	+	+			
	C1	Con											
	C3	Vac1											
	C2	Vac2		+			+				+	+	
	C5	Blks											
	C4	Soil			+	+	+	+	+	+	+	+	

Sys/Yr	Pool	Trt.	17-Dec	29-Dec	16-Jan	30-Jan	13-Feb	25-Feb	11-Mar	26-Mar	8-Apr	21-Apr	7-May
A/3	TR5	Src			+	+	+	+	+	+	+		
	A3	Con					+		+	+			
	A1	Vac1				+	+	+	+	+	+	+	
	A2	Vac2				+	+	+	+	+	+		
	A4	Blks		+		+	+	+	+		+		
	A5	Soil				+	+	+	+	+	+		
B/3	TR17	Src				+	+		+	+			
	B3	Con								+	+		
	B4	Vac1				+	+	+	+	+		+	
	B2	Vac2					+	+	+		+		
	B1	Blks				+	+	+	+	+	+		
	B5	Soil			+	+	+	+	+	+	+	+	
C/3	TR1	Src			+	+	+	+	+	+	+		
	TR2	Src											
	TR3	Src								+			
	TR4	Src			+	+	+	+	+		+		
	C1	Con											
	C3	Vac1									+		
	C2	Vac2											
	C5	Blks								+			
	C4	Soil				+	+	+	+	+	+		

The macrothricid *Macrothrix hirsuticornis*

Sys/Yr	Pool	Trtm	17-Dec	29-Dec	16-Jan	30-Jan	13-Feb	25-Feb	11-Mar	26-Mar	8-Apr	21-Apr	7-May
A/2	TR5	Src		+			+						
	A3	Con											
	A1	Vac1		+				+	+				
	A2	Vac2											
	A4	Blocks											
	A5	Soil											
B/2	TR17	Src	+		+		+						
	B3	Con											
	B4	Vac1					+						
	B2	Vac2		+									
	B1	Blocks											
	B5	Soil			+								
C/2	TR1	Src		+	+	+	+	+	+				
	TR2	Src											
	TR3	Src		+	+								
	TR4	Src	+	+	+	+	+						
	C1	Con											
	C3	Vac1											
	C2	Vac2					+						
	C5	Blocks											
	C4	Soil			+								

Sys/Yr	Pool	Trtm	17-Dec	29-Dec	16-Jan	30-Jan	13-Feb	25-Feb	11-Mar	26-Mar	8-Apr	21-Apr	7-May
A/3	TR5	Src											
	A3	Con											
	A1	Vac1								+			
	A2	Vac2											
	A4	Blocks											
	A5	Soil						+					
B/3	TR17	Src				+							
	B3	Con											
	B4	Vac1											
	B2	Vac2											
	B1	Blocks											
	B5	Soil						+					
C/3	TR1	Src			+			+	+				
	TR2	Src											
	TR3	Src			+	+	+	+	+				
	TR4	Src											
	C1	Con											
	C3	Vac1											
	C2	Vac2											
	C5	Blocks											
	C4	Soil					+	+					

The macrothricid *Macrothrix sp.*

Sys/Yr	Pool	Trtm	17-Dec	29-Dec	16-Jan	30-Jan	13-Feb	25-Feb	11-Mar	26-Mar	8-Apr	21-Apr	7-May
A/2	TR5	Src											
	A3	Con											
	A1	Vac1										+	
	A2	Vac2											
	A4	Blocks						+	+	+	+		
	A5	Soil									+		
B/2	TR17	Src								+			
	B3	Con								+	+		
	B4	Vac1					+	+	+	+			
	B2	Vac2						+	+				+
	B1	Blocks				+					+	+	
	B5	Soil					+			+			+
C/2	TR1	Src						+	+	+	+		
	TR2	Src											
	TR3	Src					+	+	+				
	TR4	Src											
	C1	Con								+			
	C3	Vac1			+		+	+	+		+		
	C2	Vac2				+	+	+	+	+	+	+	
	C5	Blocks										+	
	C4	Soil					+	+	+		+		

Sys/Yr	Pool	Trtm	17-Dec	29-Dec	16-Jan	30-Jan	13-Feb	25-Feb	11-Mar	26-Mar	8-Apr	21-Apr	7-May
A/3	TR5	Src											
	A3	Con											
	A1	Vac1											
	A2	Vac2										+	
	A4	Blocks											
	A5	Soil		+	+					+			
B/3	TR17	Src											
	B3	Con			+	+		+				+	
	B4	Vac1		+		+			+	+		+	
	B2	Vac2		+		+				+	+		
	B1	Blocks		+							+	+	
	B5	Soil		+		+			+			+	
C/3	TR1	Src								+			
	TR2	Src											
	TR3	Src		+						+			
	TR4	Src											
	C1	Con				+							
	C3	Vac1					+			+		+	
	C2	Vac2		+		+			+	+			
	C5	Blocks		+	+	+	+		+	+		+	
	C4	Soil		+	+	+				+		+	

The moinid *Moina wierzejskii*

Sys/Yr	Pool	Trtm	17-Dec	29-Dec	16-Jan	30-Jan	13-Feb	25-Feb	11-Mar	26-Mar	8-Apr	21-Apr	7-May
A/2	TR5	Src											
	A3	Con									+		
	A1	Vac1											
	A2	Vac2											
	A4	Blocks	+	+									
	A5	Soil		+	+								
B/2	TR17	Src											
	B3	Con		+			+	+	+	+	+	+	
	B4	Vac1	+	+	+								
	B2	Vac2		+	+	+	+			+		+	+
	B1	Blocks		+	+	+	+	+	+	+	+	+	+
	B5	Soil		+			+	+	+				+
C/2	TR1	Src											
	TR2	Src											
	TR3	Src											
	TR4	Src											
	C1	Con	+	+	+	+	+	+	+	+	+	+	+
	C3	Vac1		+	+	+		+	+	+	+	+	
	C2	Vac2	+		+	+	+	+	+	+	+	+	
	C5	Blocks				+	+	+	+	+	+	+	
	C4	Soil		+	+	+	+	+	+	+			

Sys/Yr	Pool	Trtm	17-Dec	29-Dec	16-Jan	30-Jan	13-Feb	25-Feb	11-Mar	26-Mar	8-Apr	21-Apr	7-May
A/3	TR5	Src											
	A3	Con			+								
	A1	Vac1											
	A2	Vac2		+									
	A4	Blocks											
	A5	Soil											
B/3	TR17	Src								+	+		
	B3	Con		+	+	+							
	B4	Vac1			+								
	B2	Vac2		+	+	+	+	+					
	B1	Blocks			+								
	B5	Soil		+	+								
C/3	TR1	Src											
	TR2	Src											
	TR3	Src											
	TR4	Src			+								
	C1	Con		+	+	+	+	+	+				
	C3	Vac1		+	+	+	+	+					
	C2	Vac2			+		+						
	C5	Blocks		+	+	+	+	+	+	+	+	+	
	C4	Soil		+	+	+		+					

FIGURE D1-ANNUAL TRENDS IN INVERTEBRATE POPULATIONS

Each page of this figure shows the numbers of a given taxon at each sampling period in year 2 and year 3. Data from all created pools including controls are combined; the average annual numbers in each type of pool can be seen in Table D1. Taxa are presented approximately in the order from more primitive to more advanced evolutionarily.

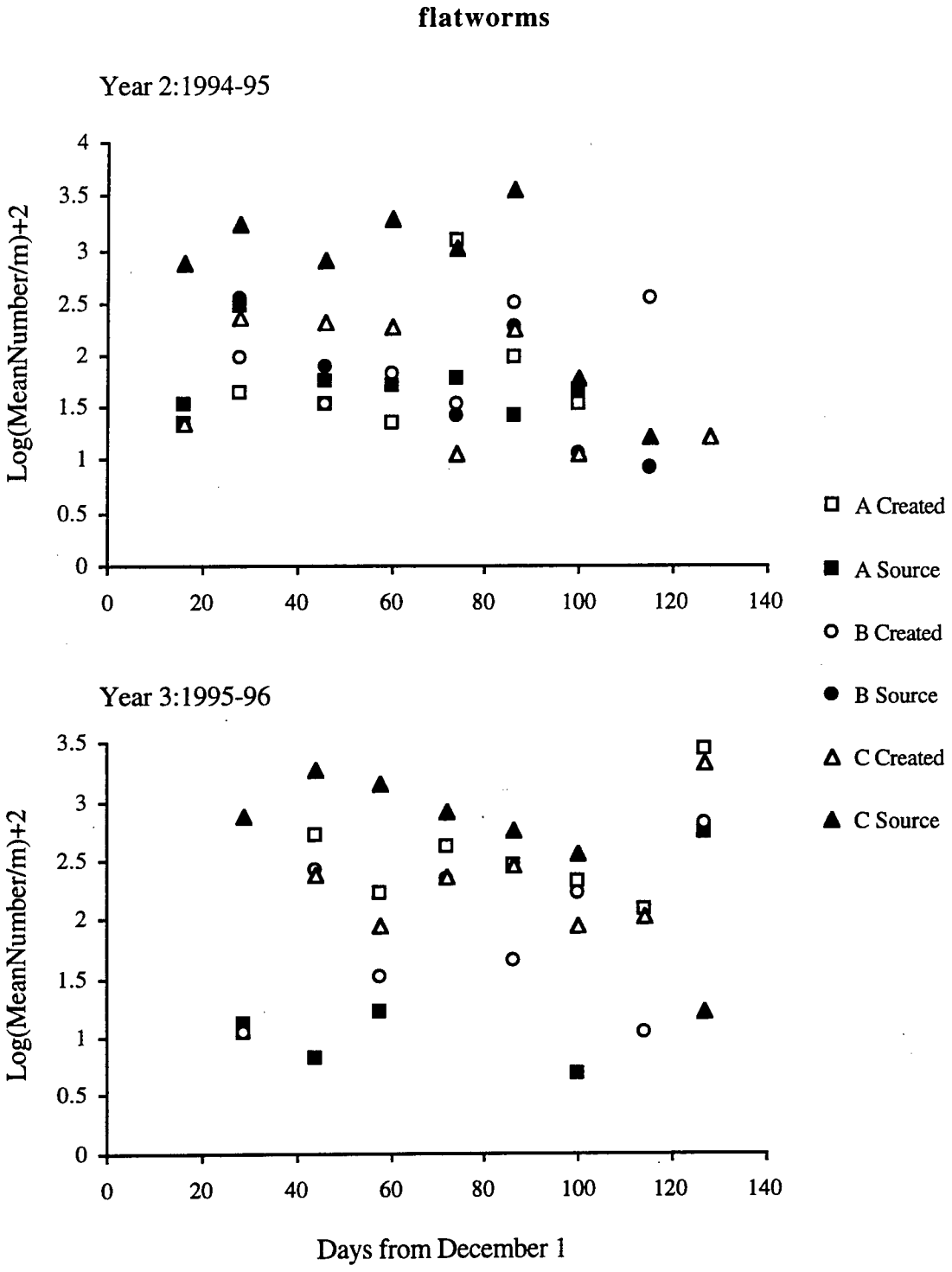
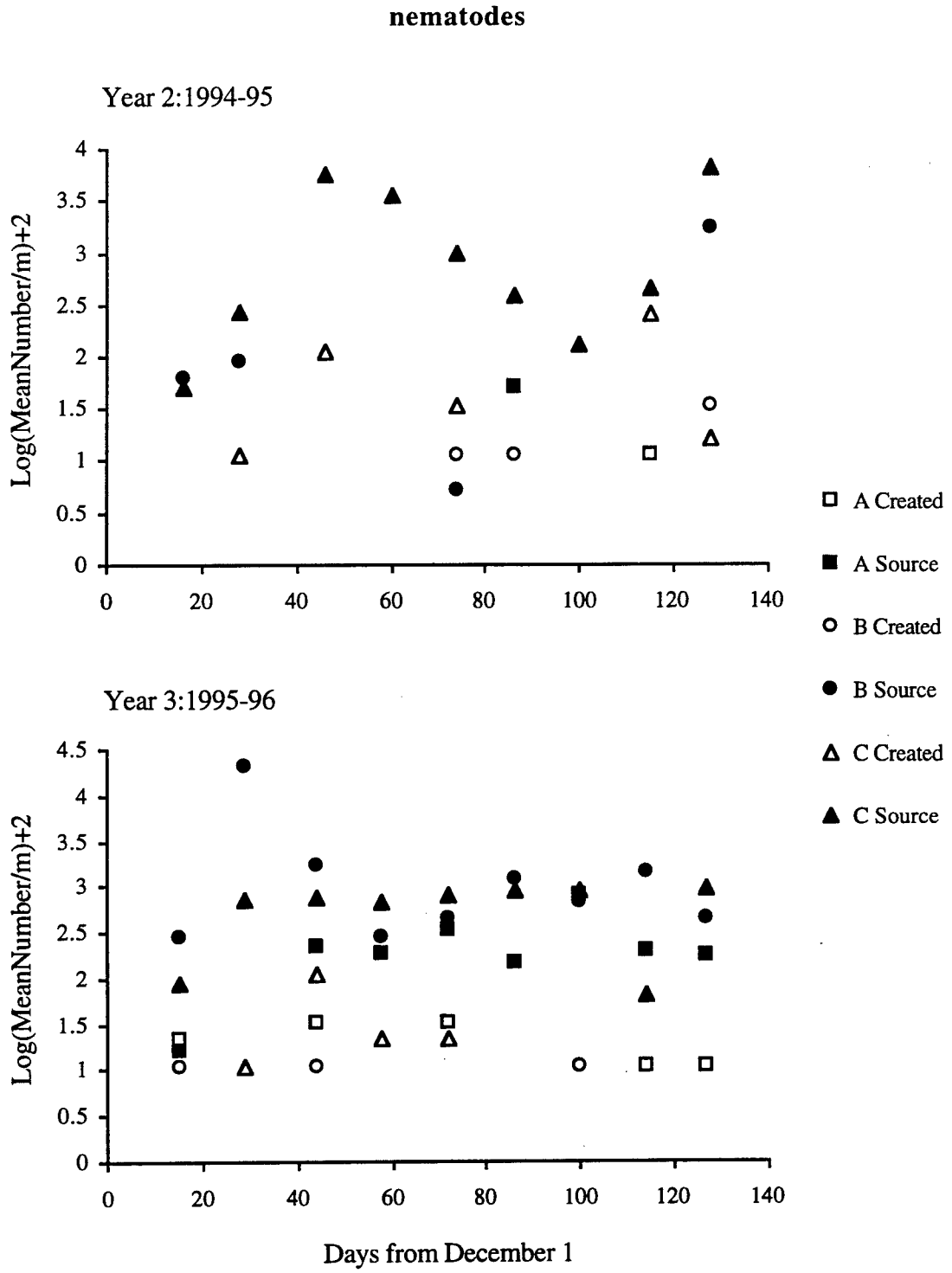


Figure D1, invertebrate trends, continued.



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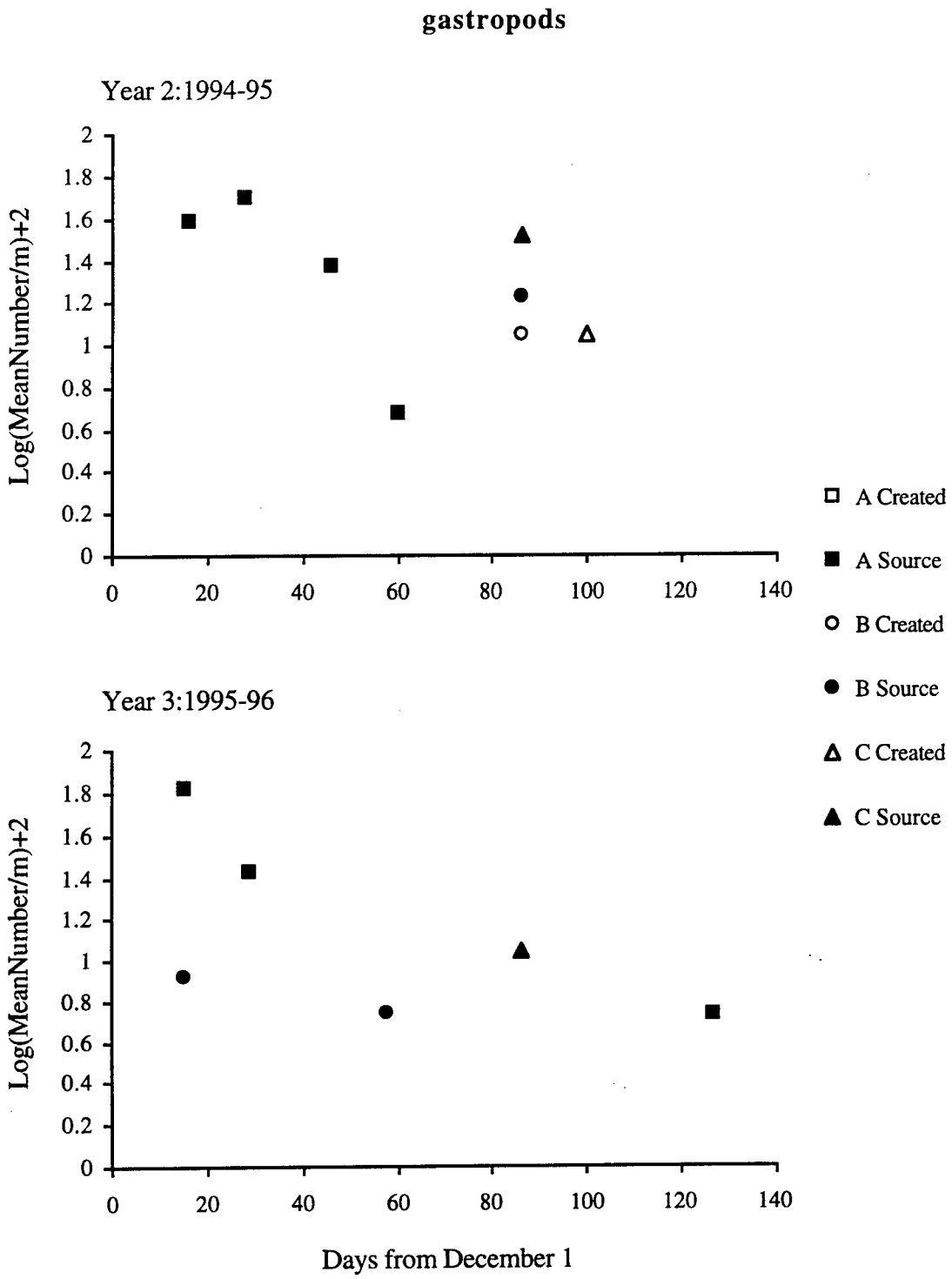

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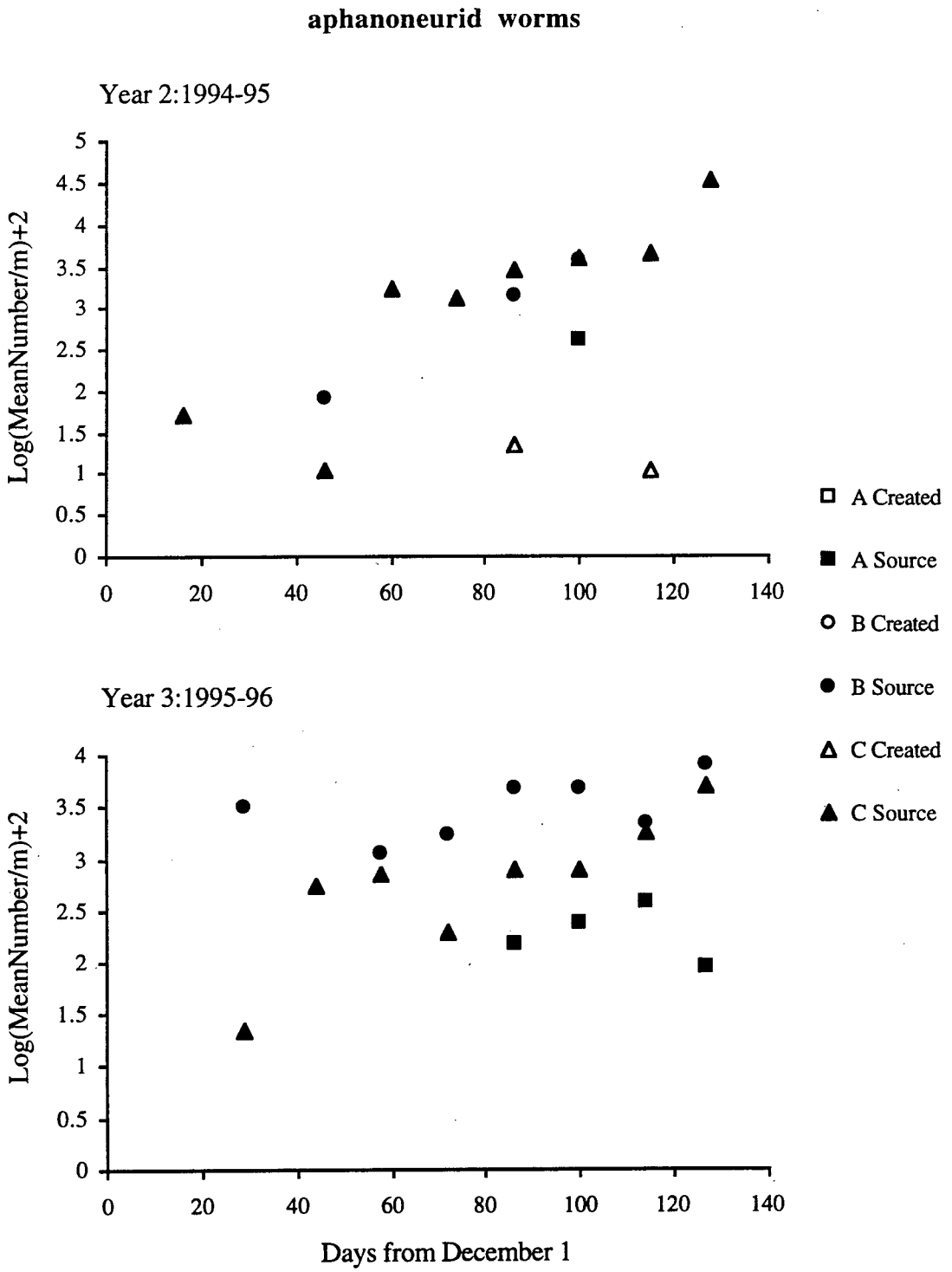

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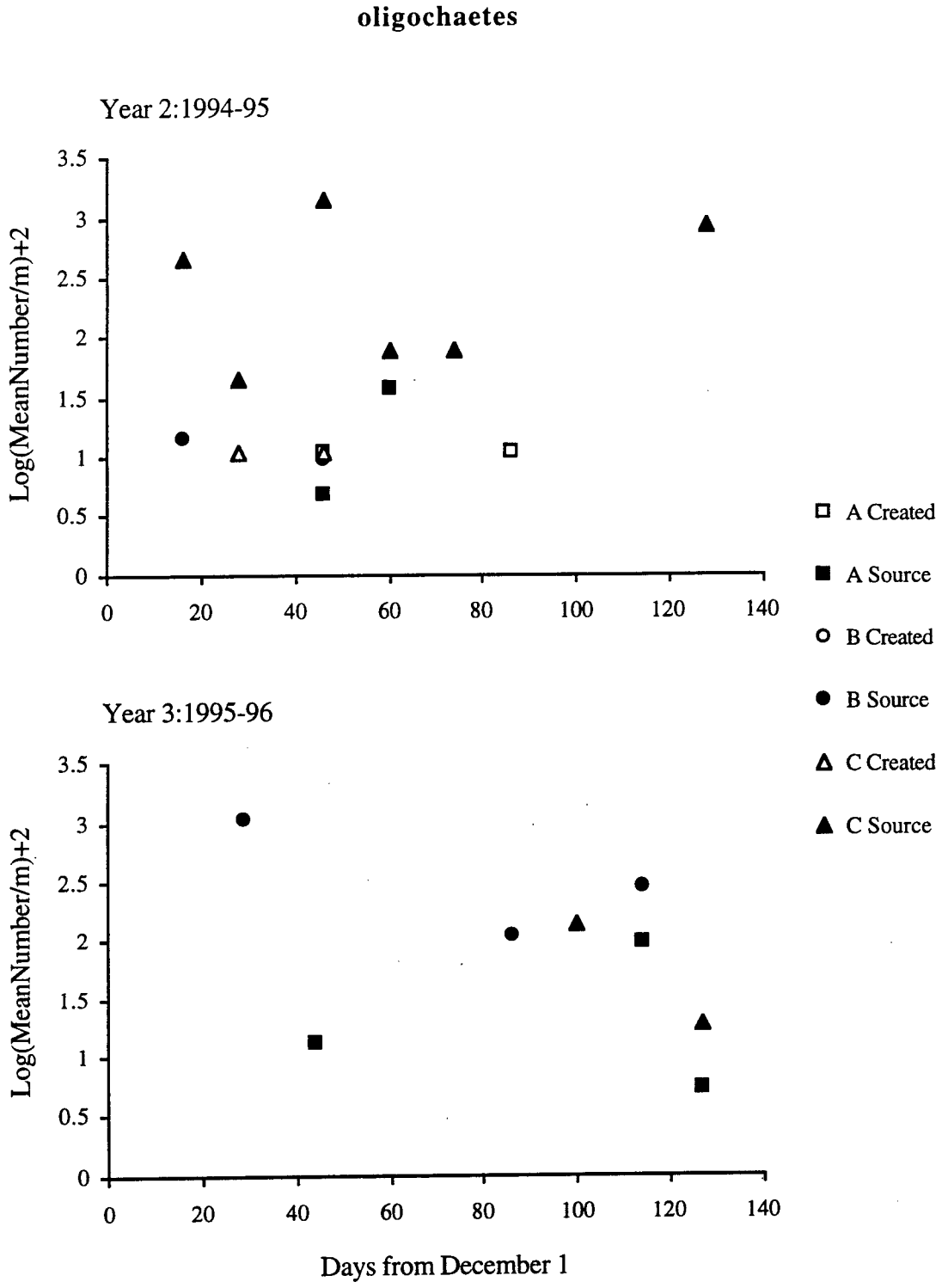

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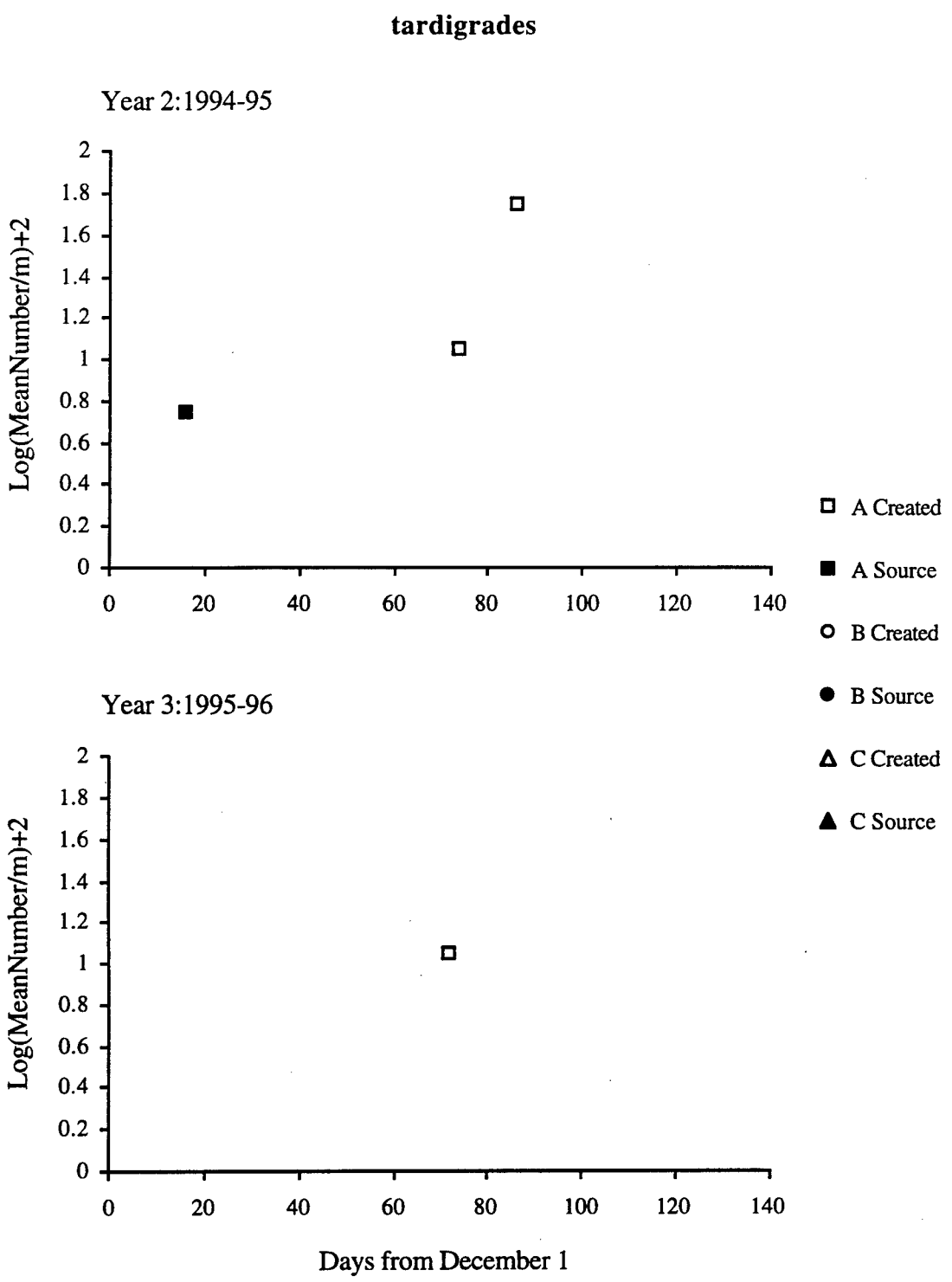

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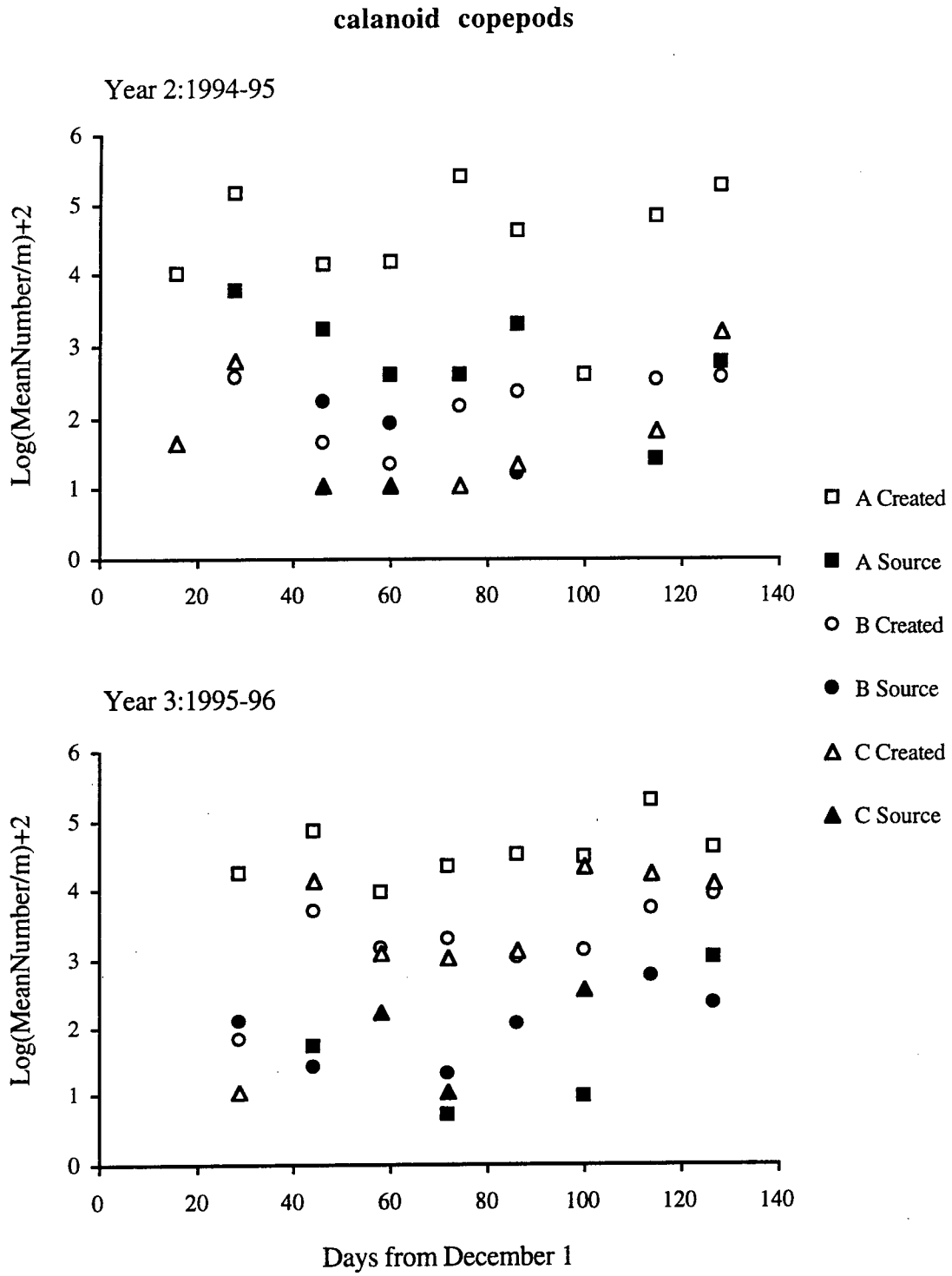

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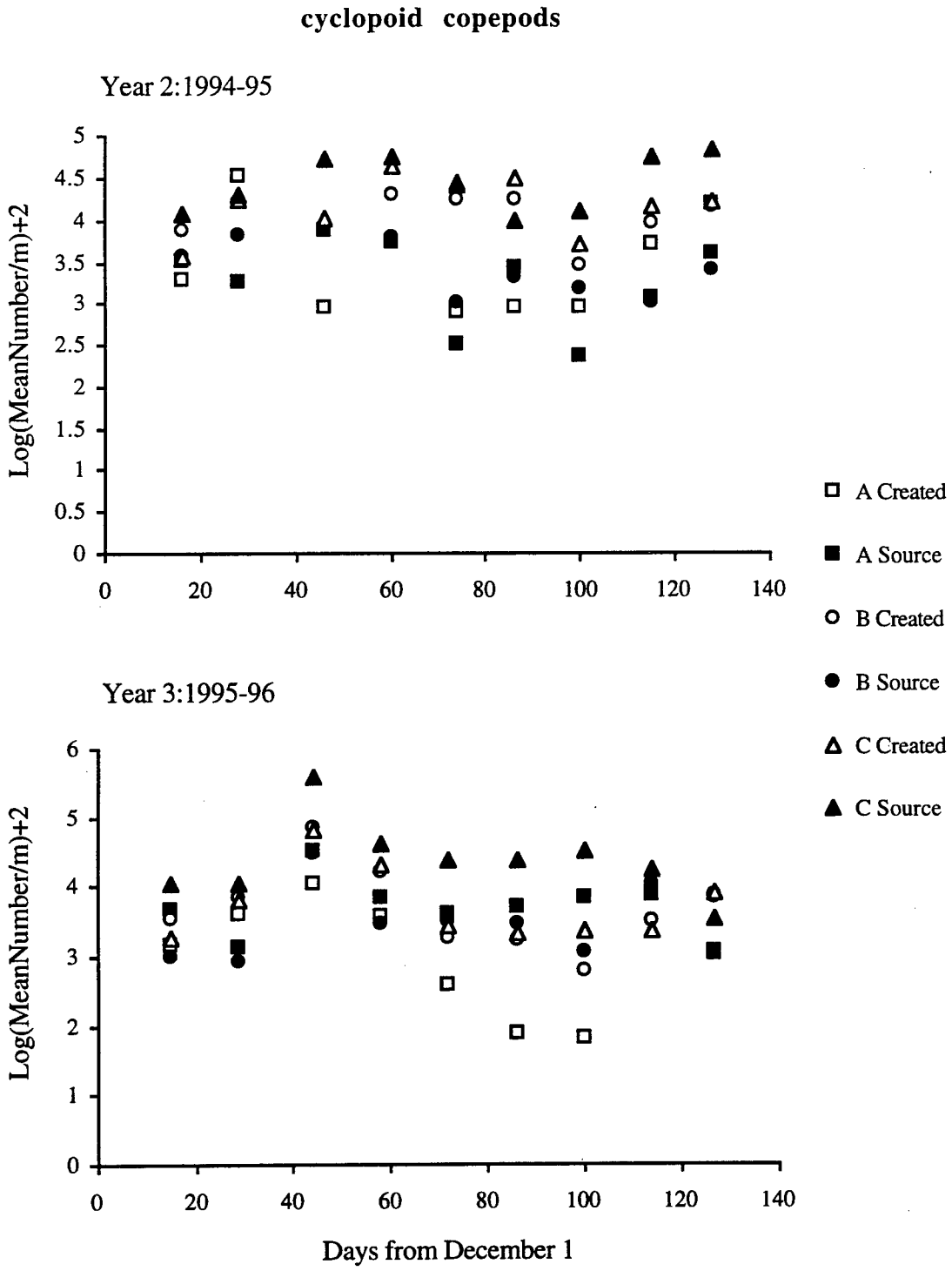

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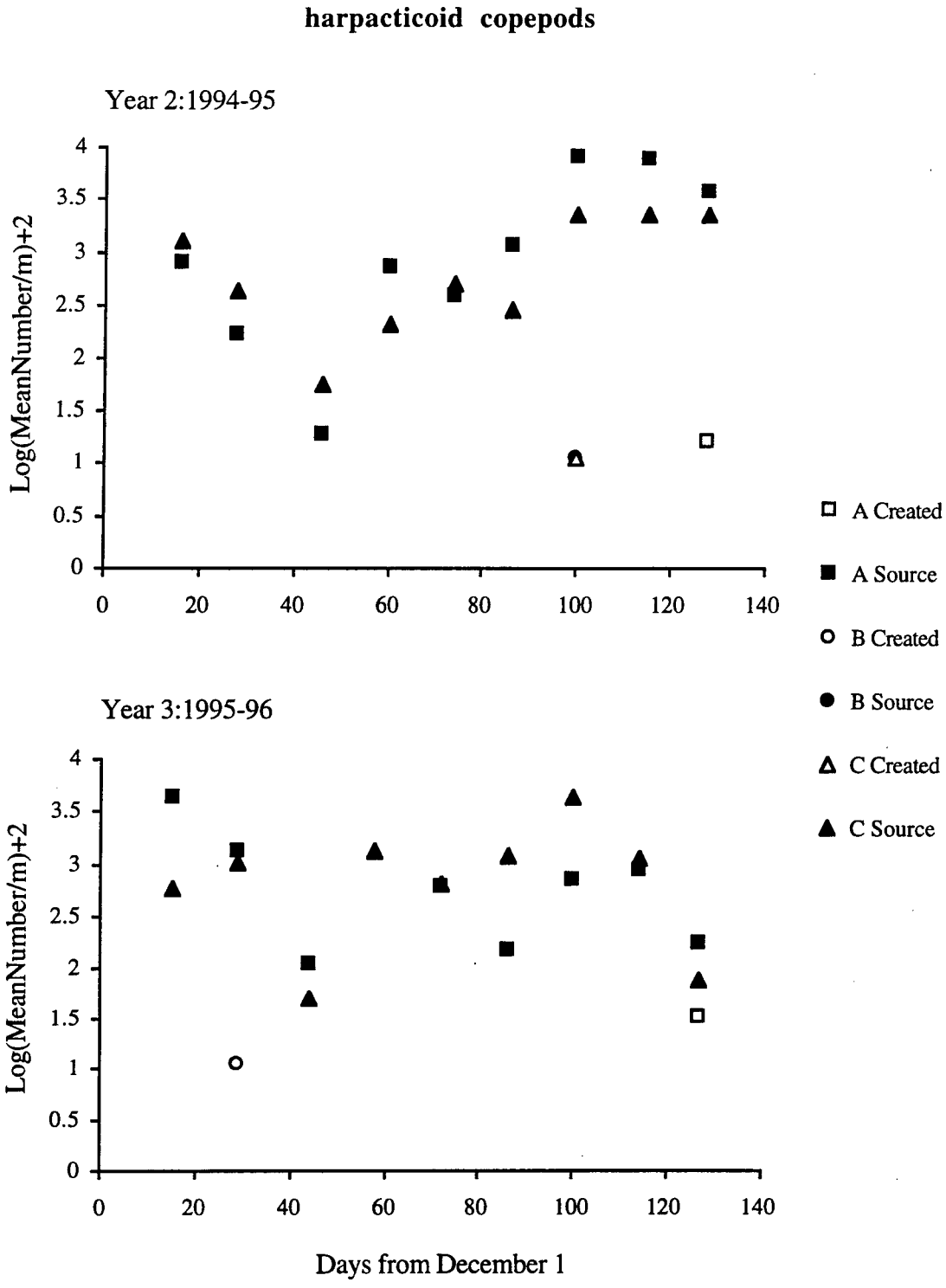

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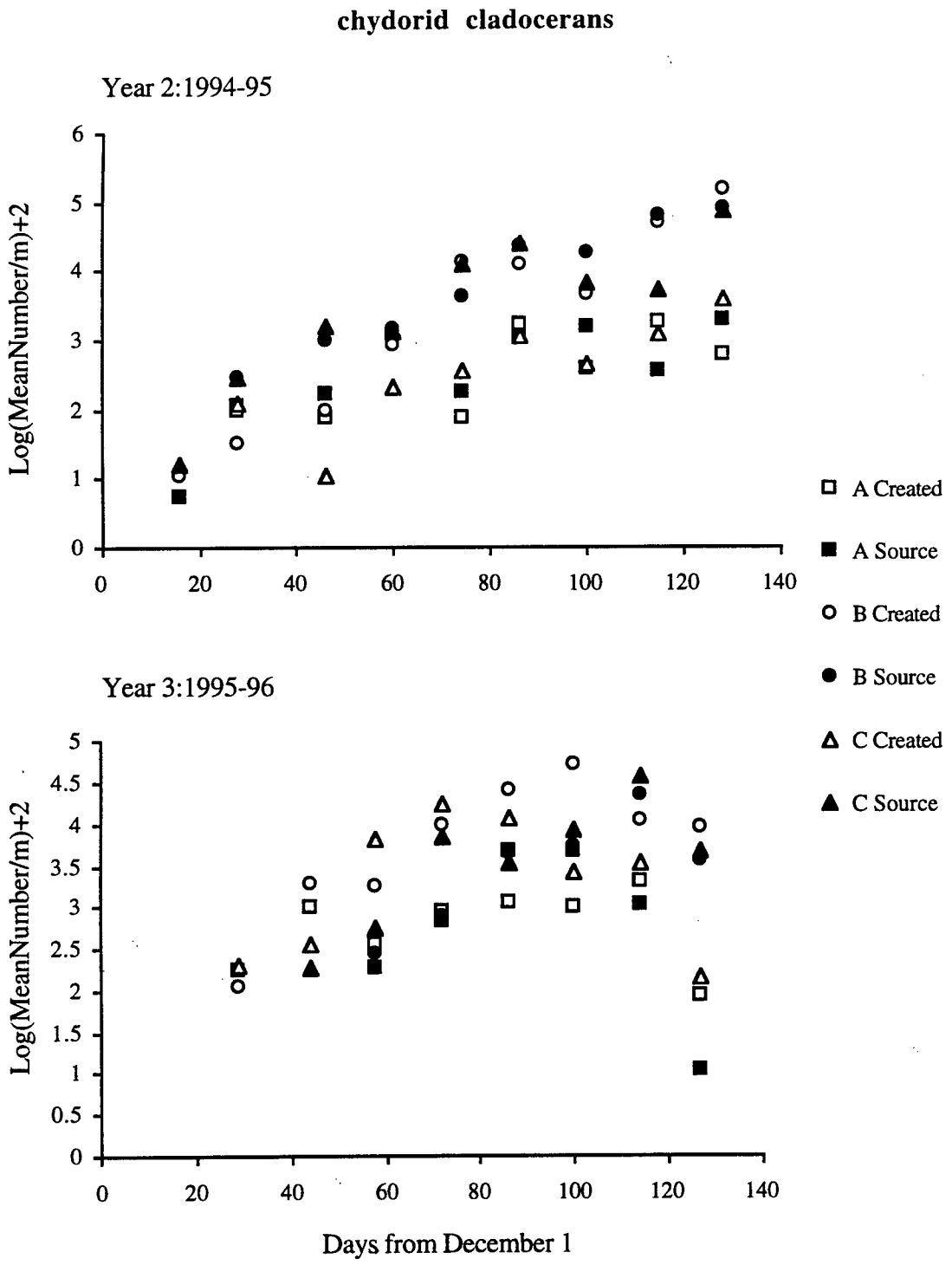

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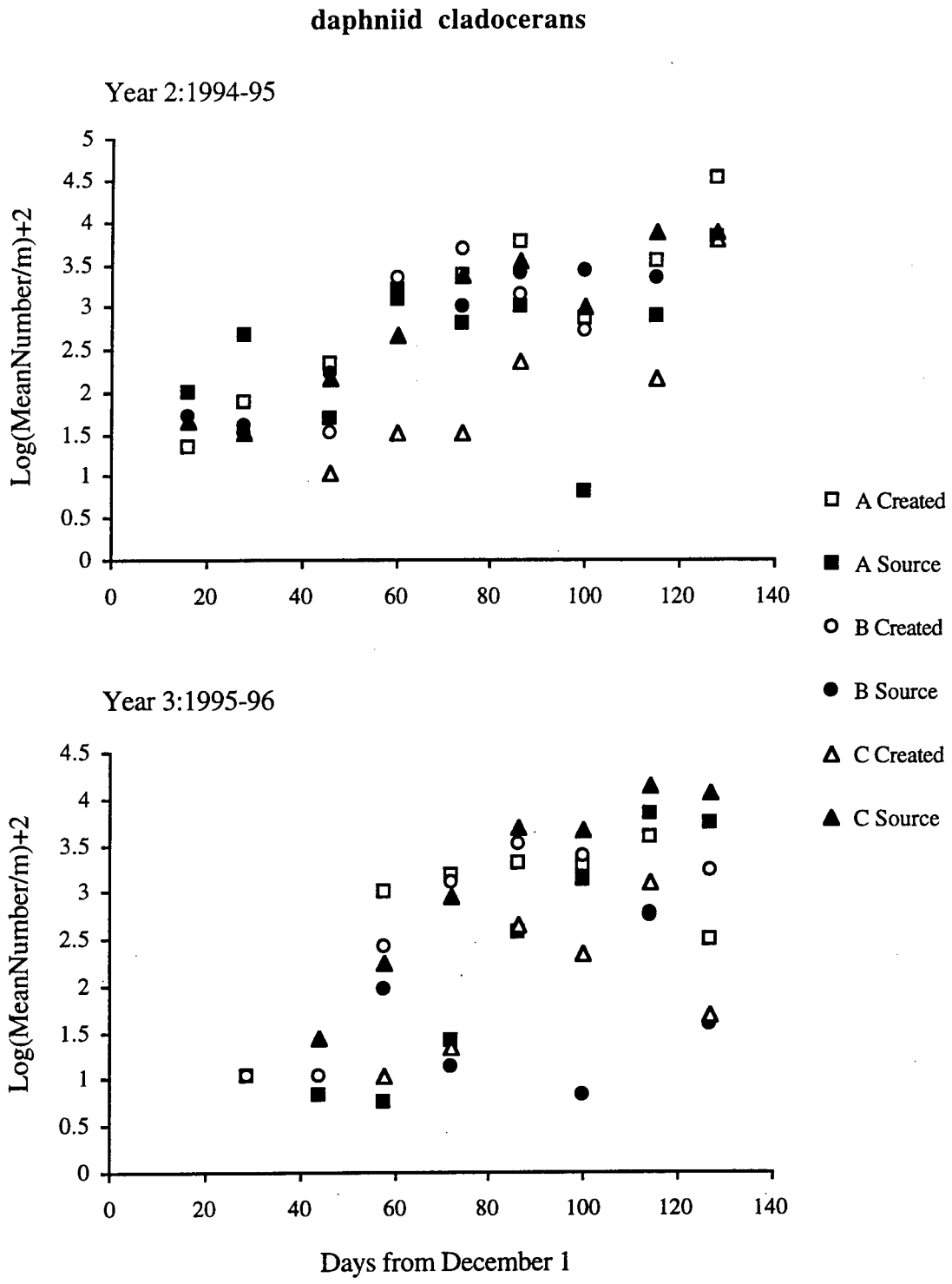

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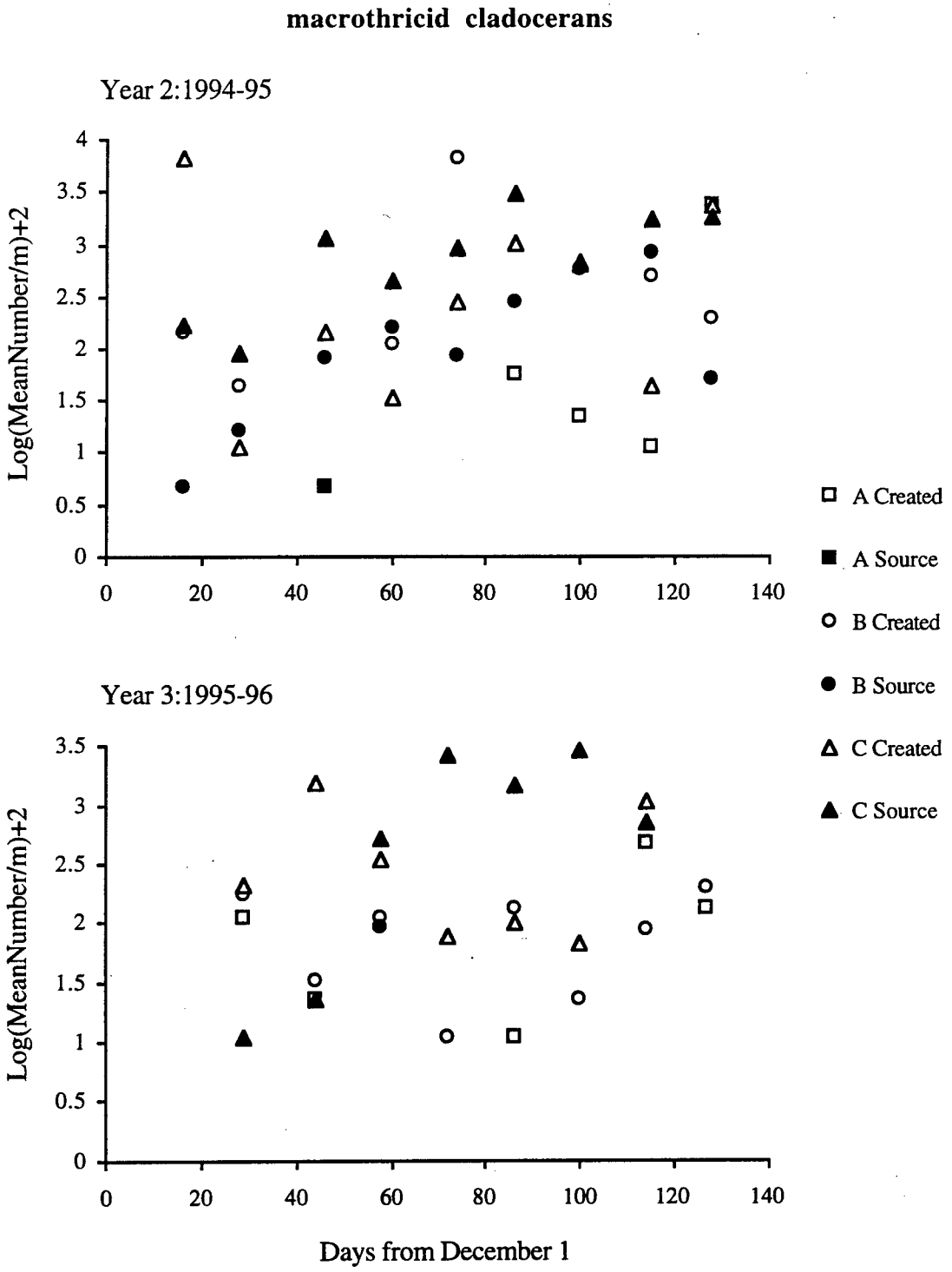

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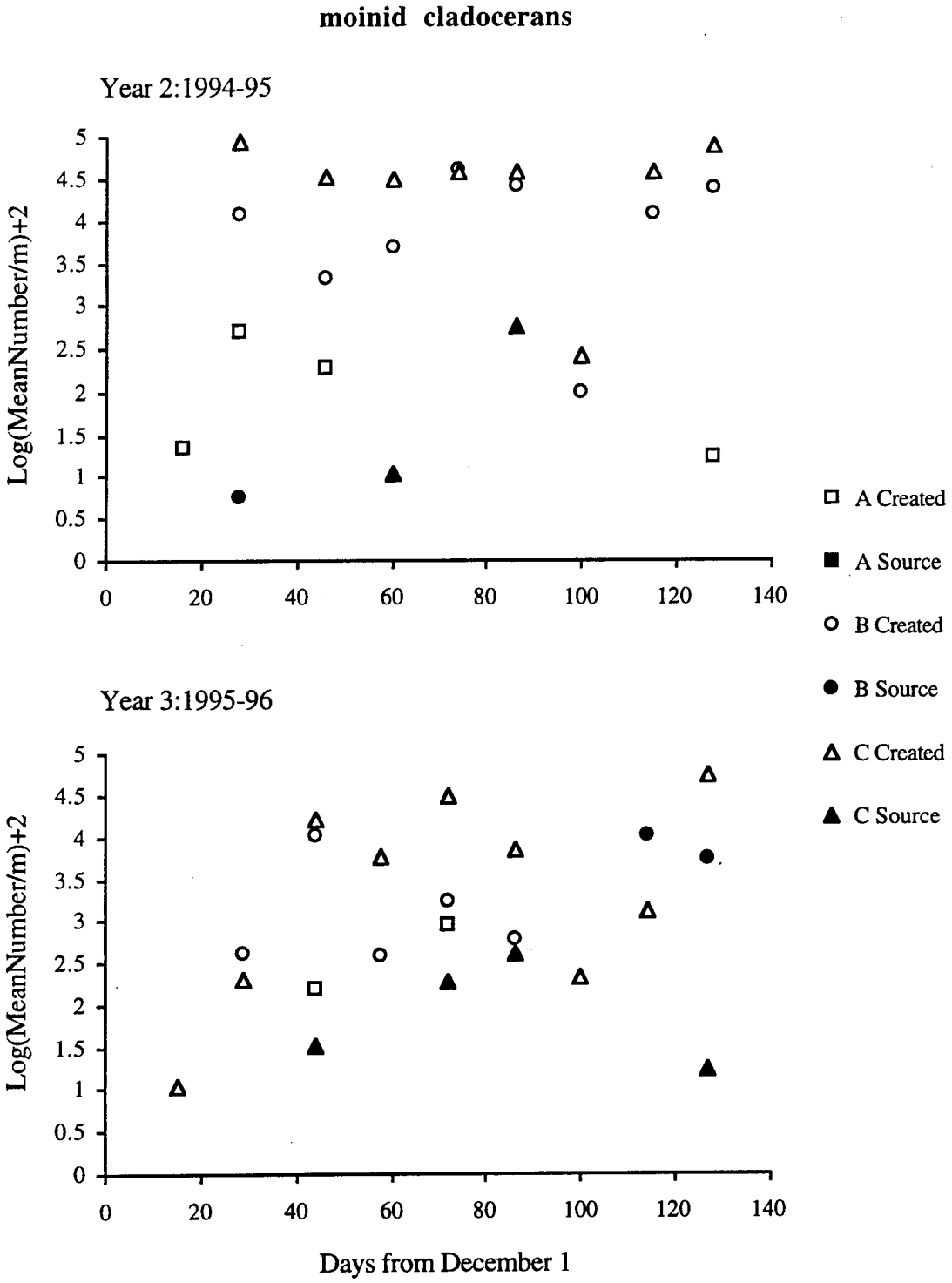

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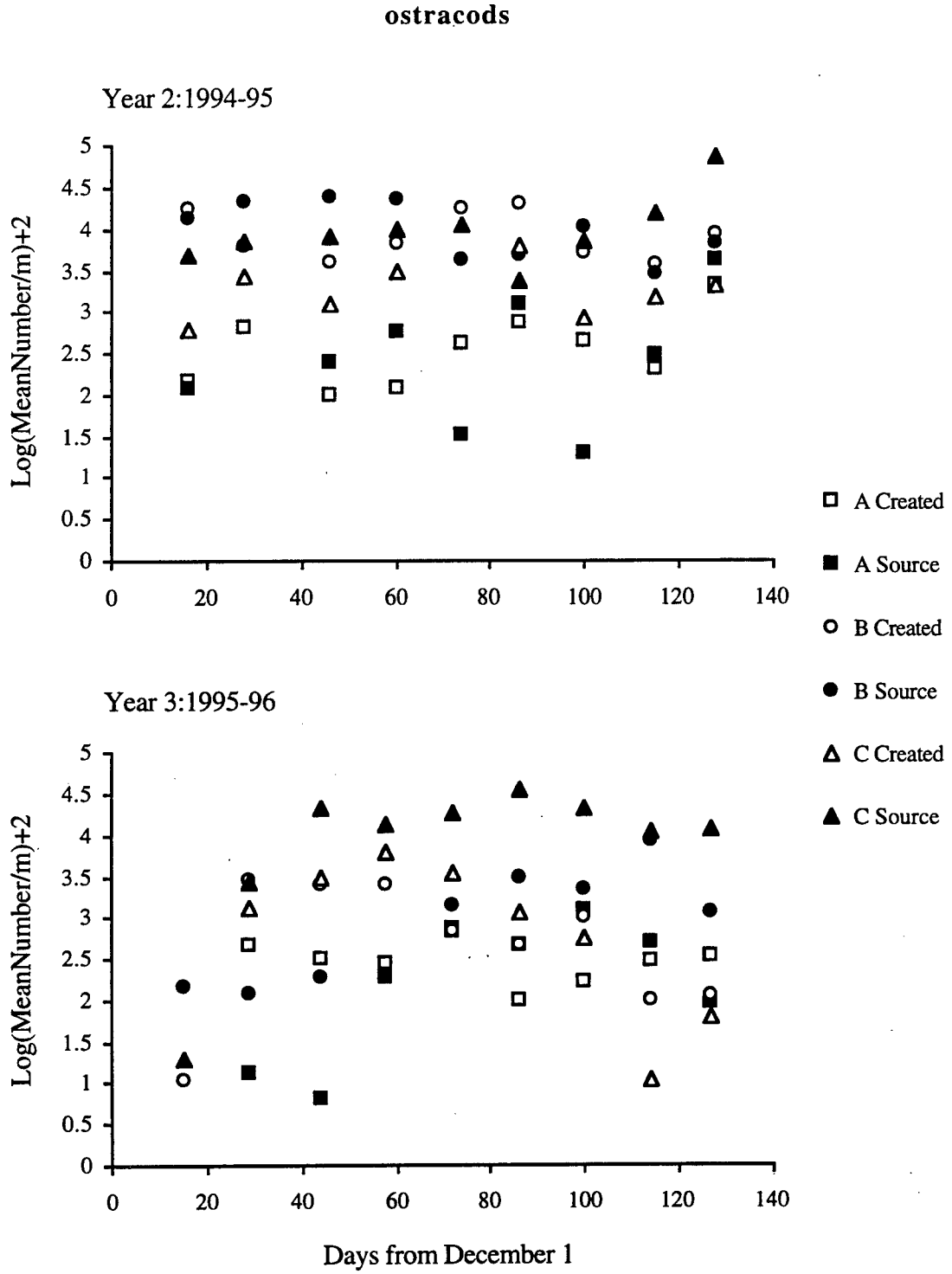

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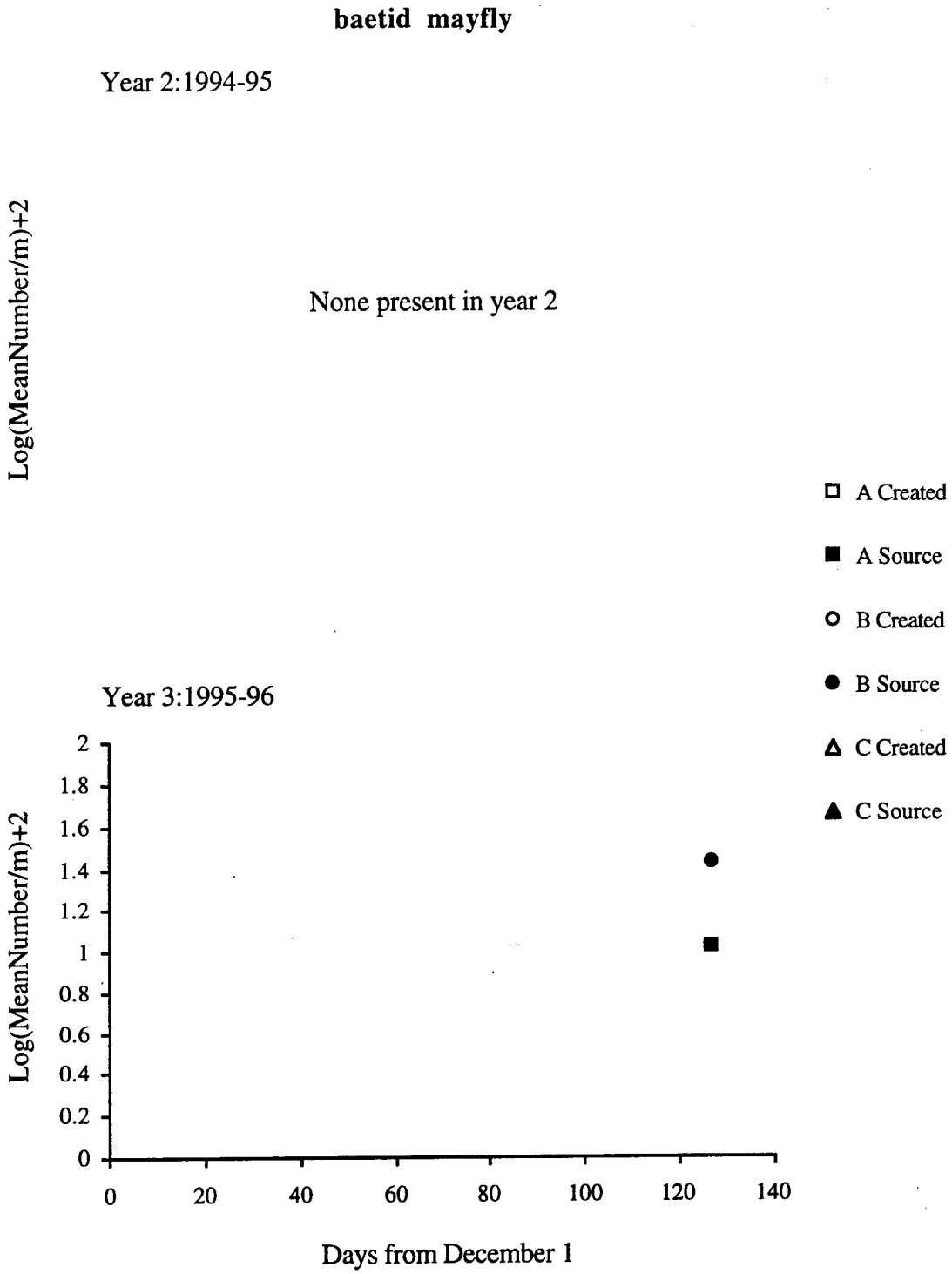

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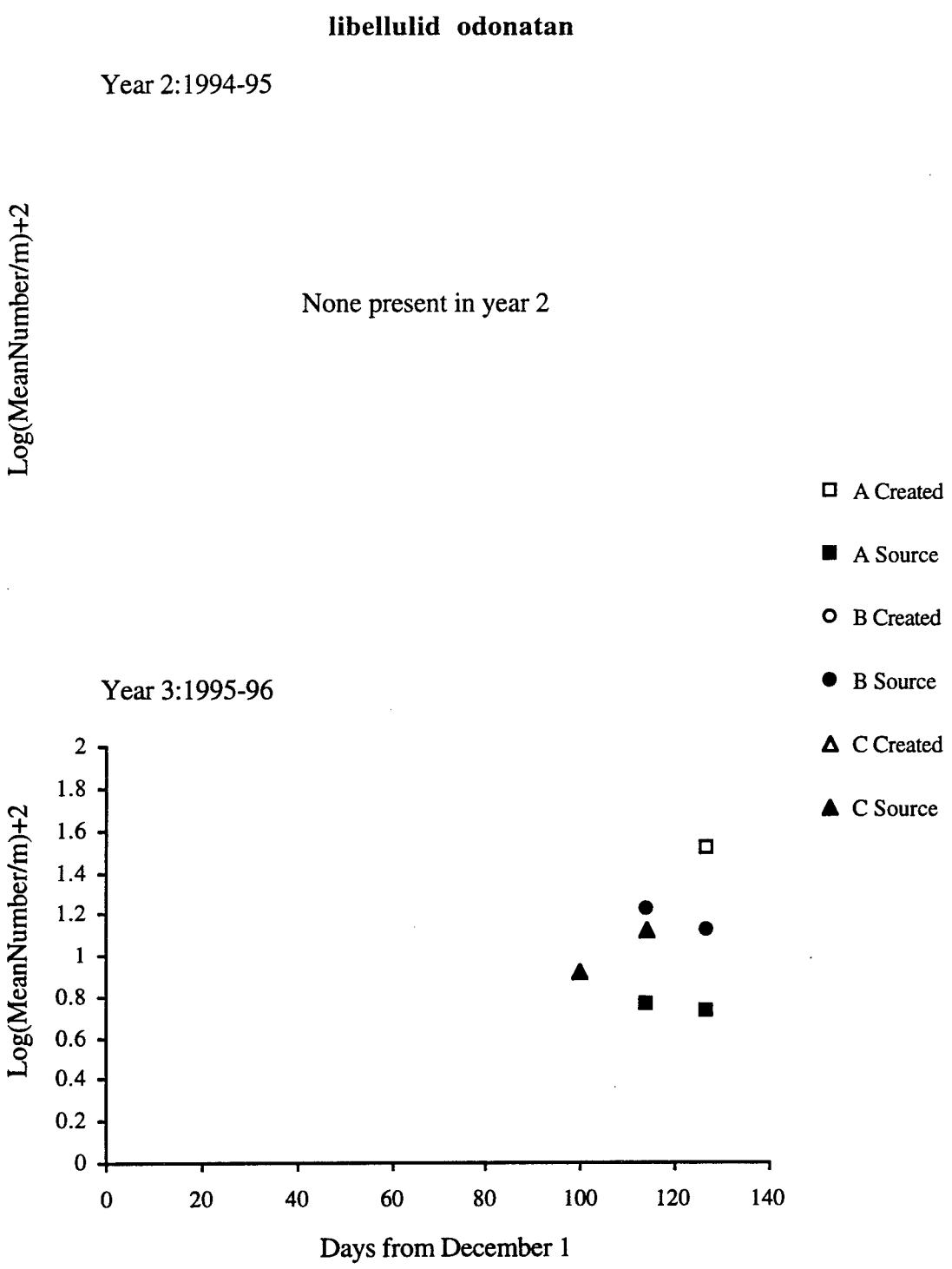

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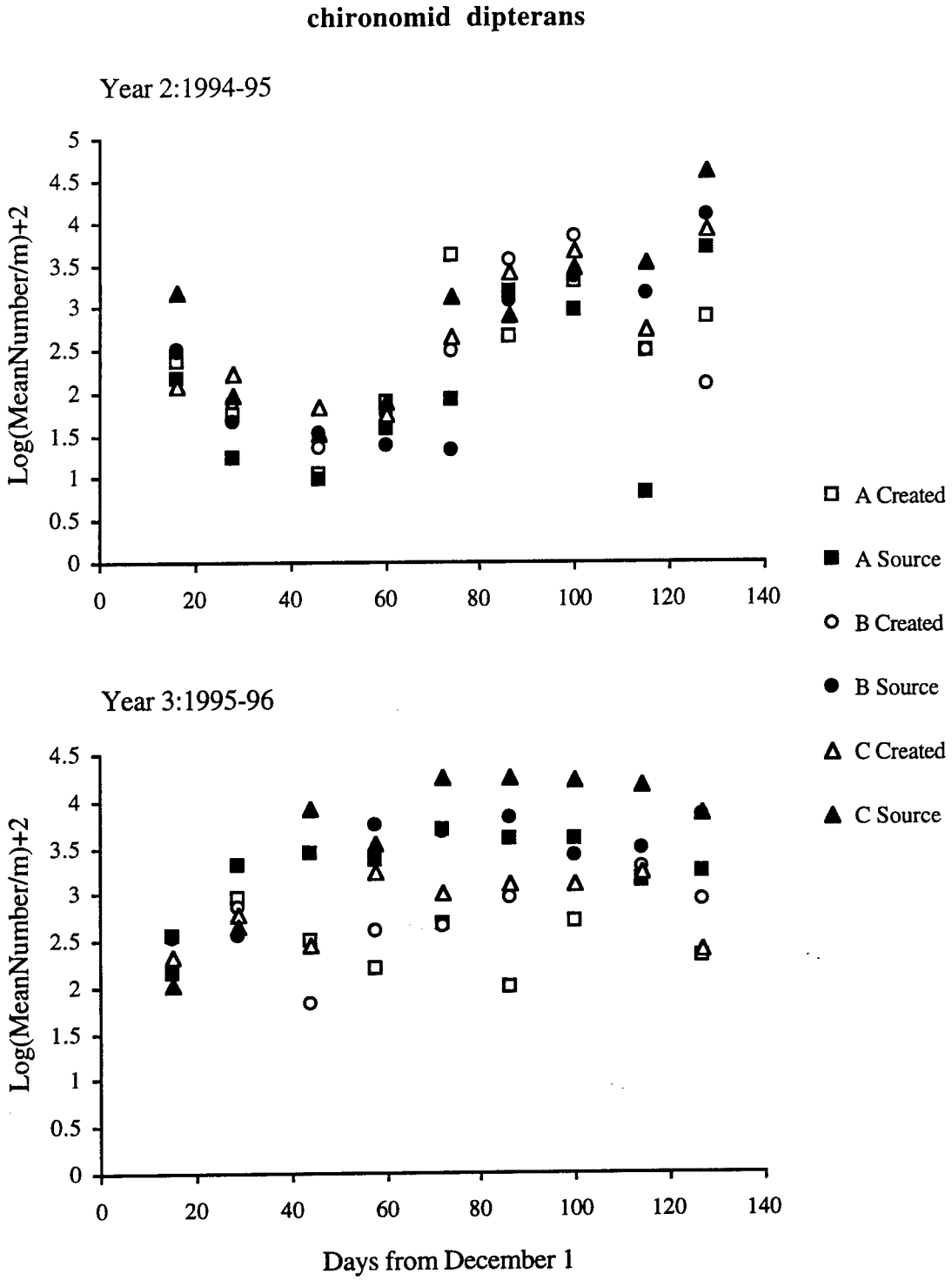

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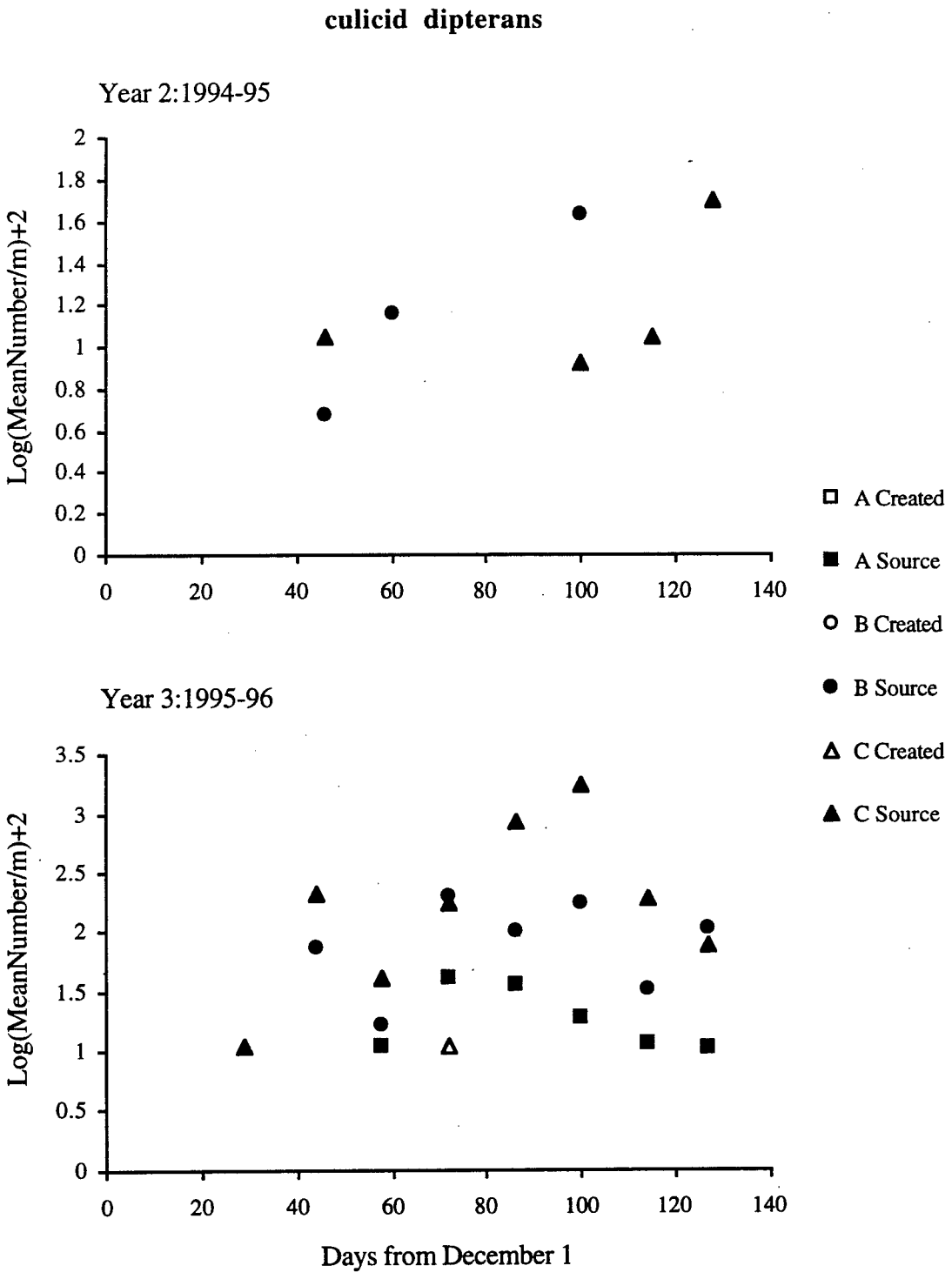

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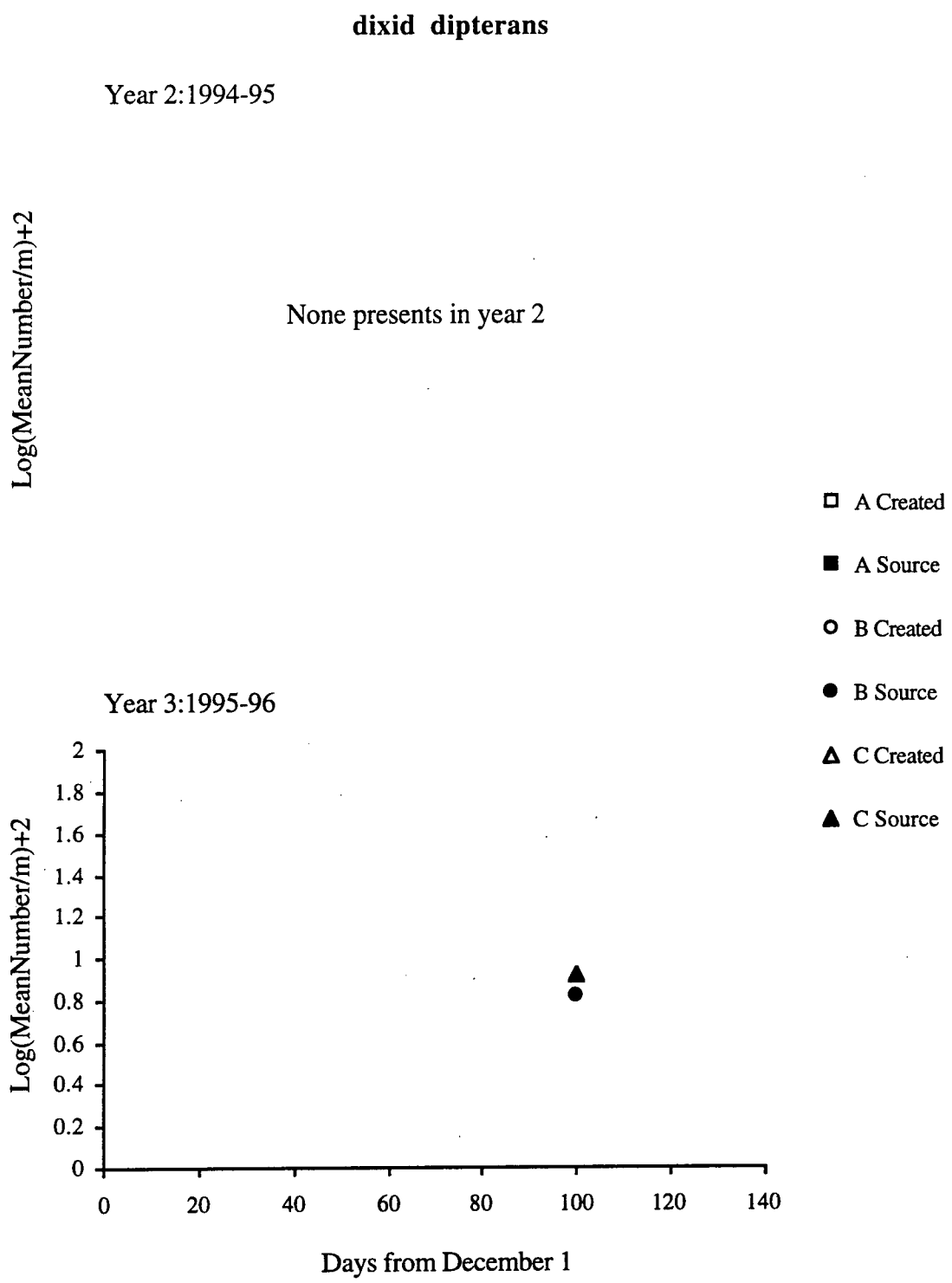

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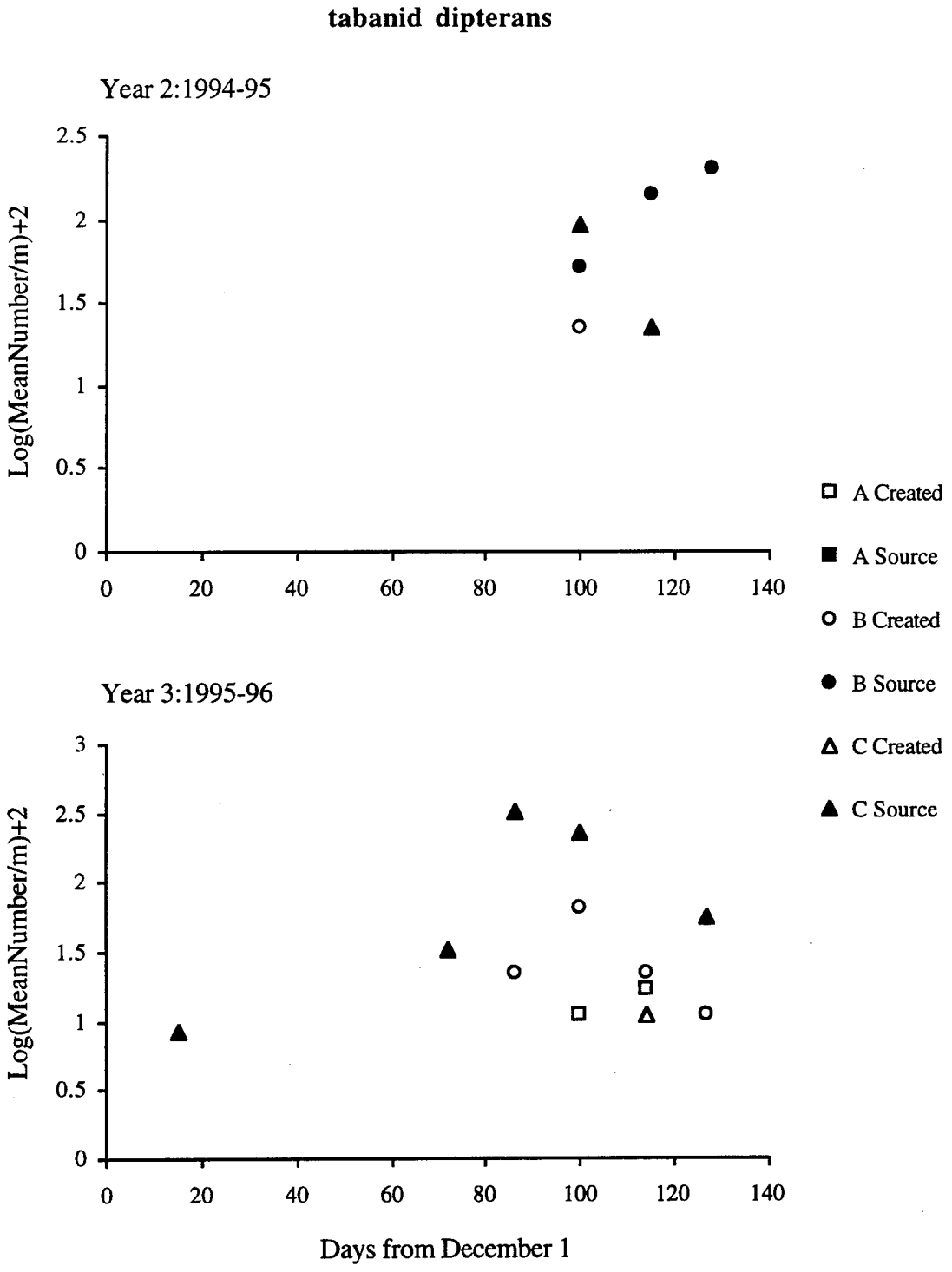

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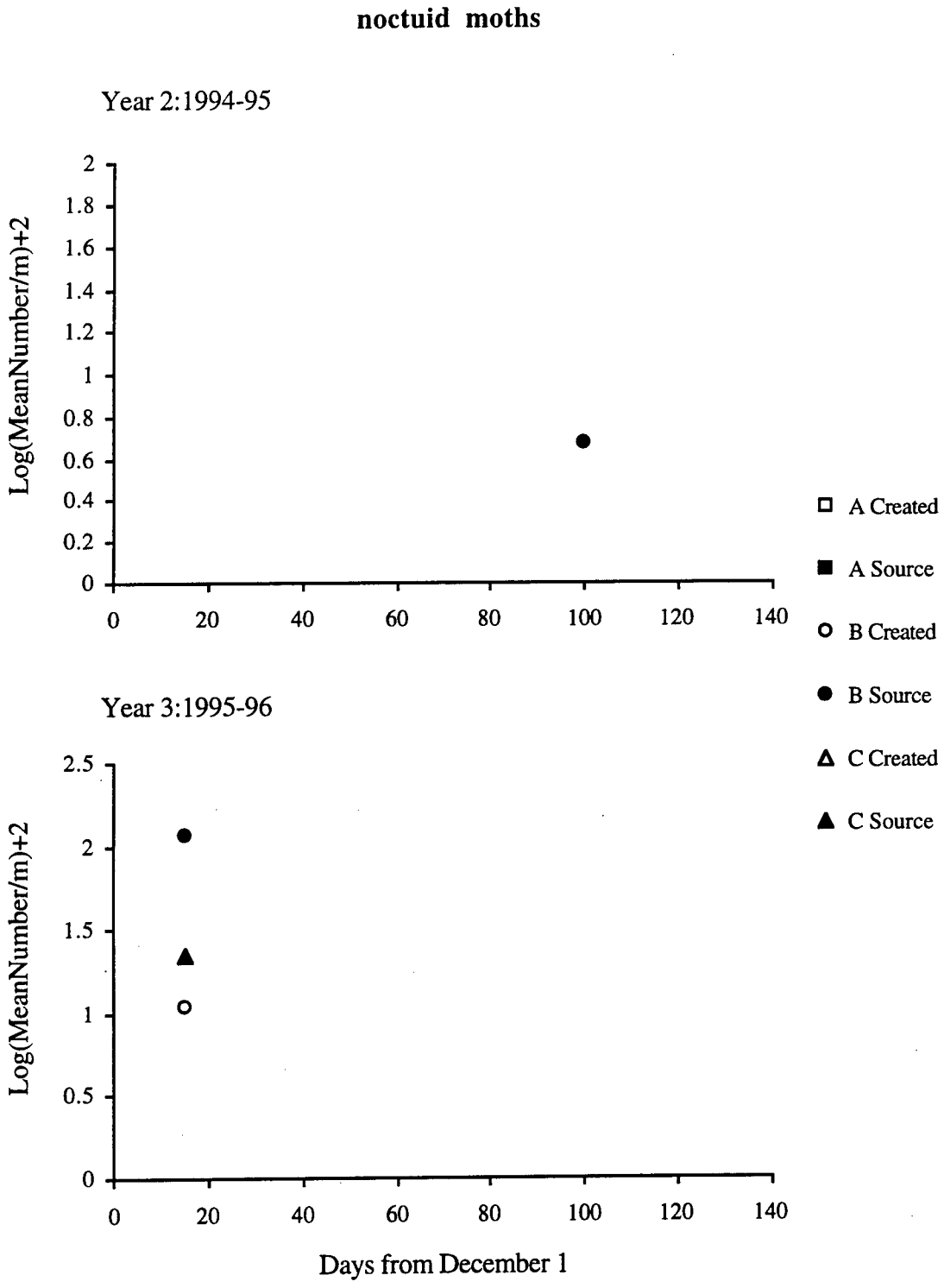

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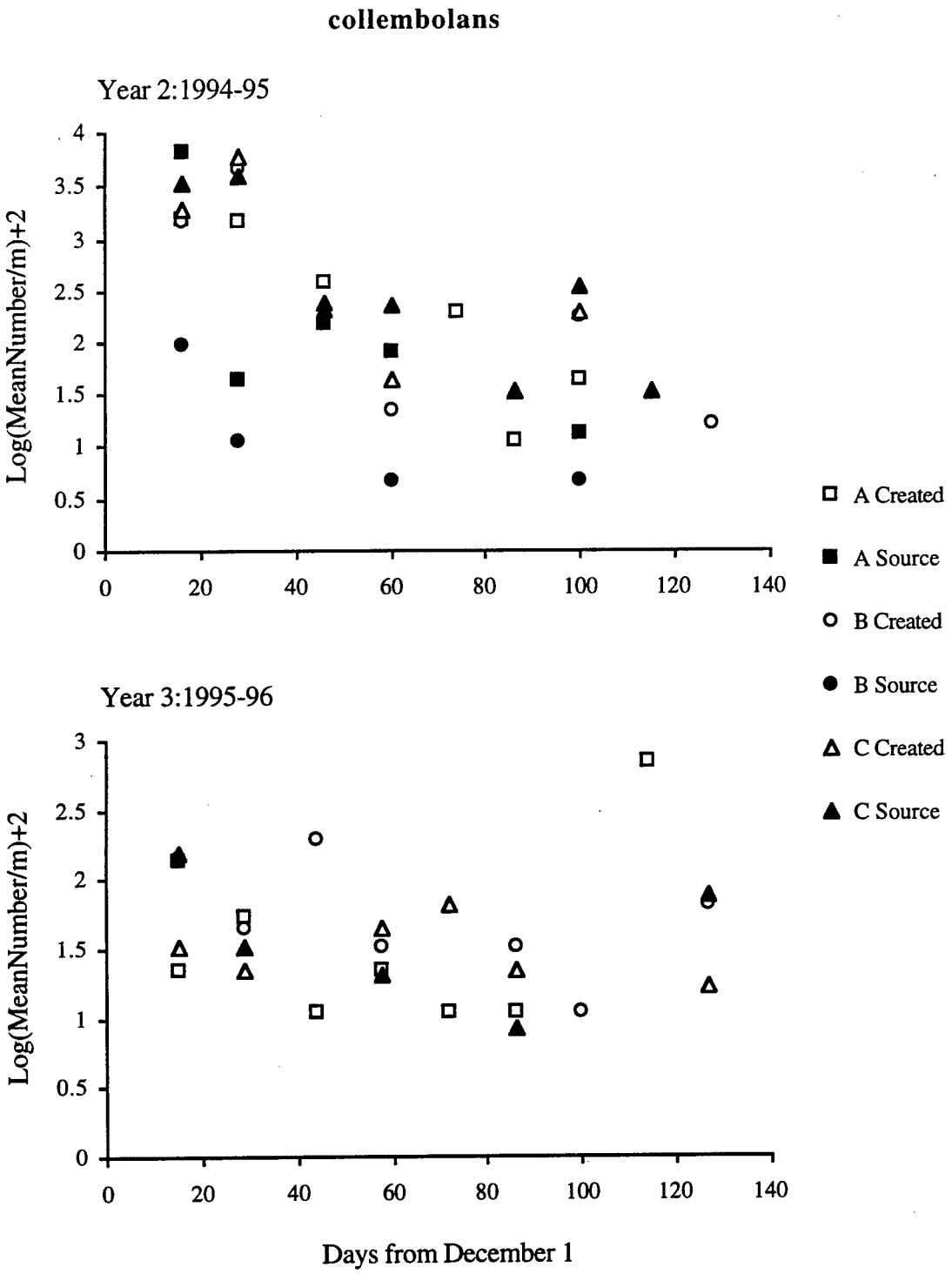

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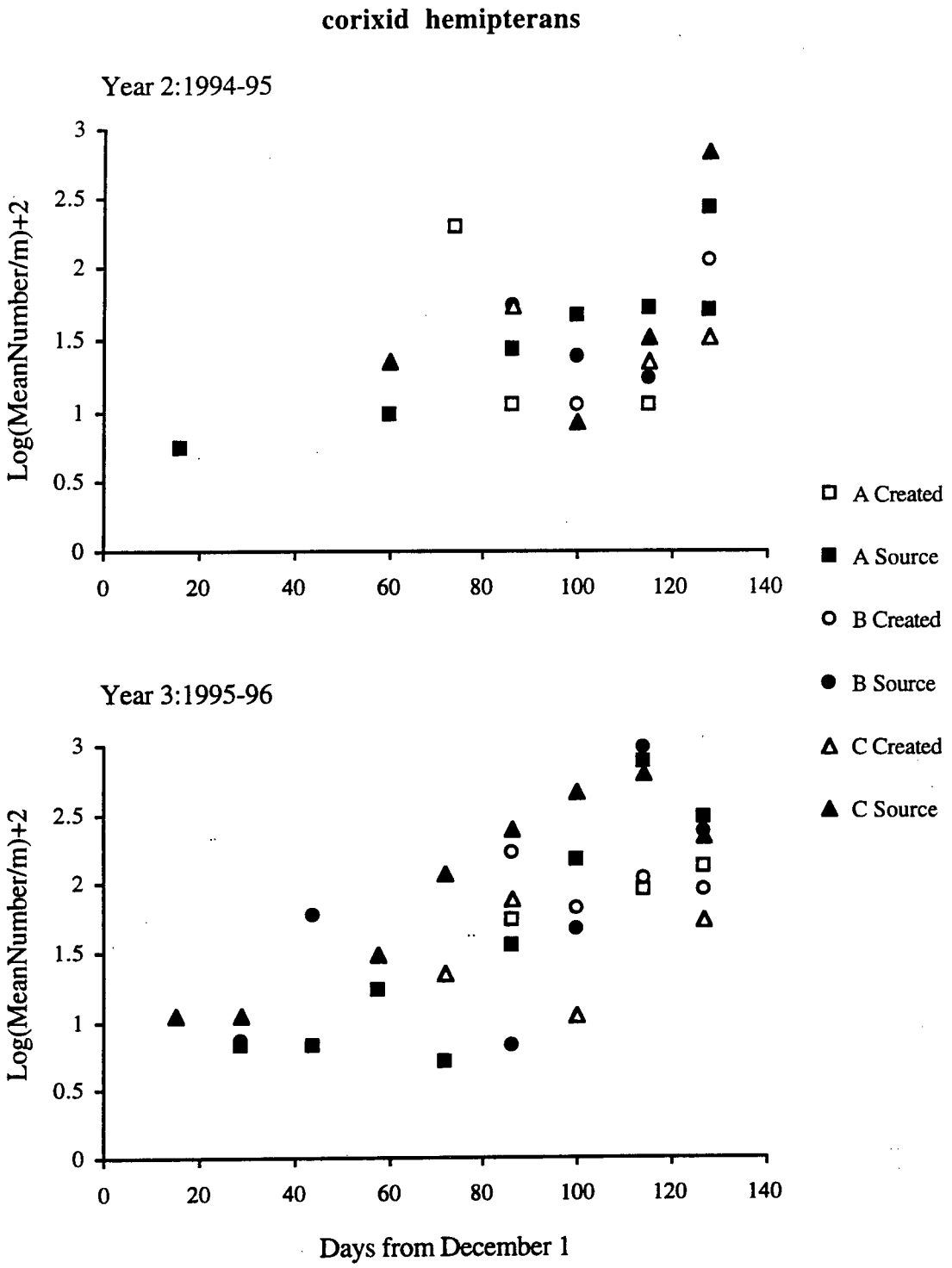

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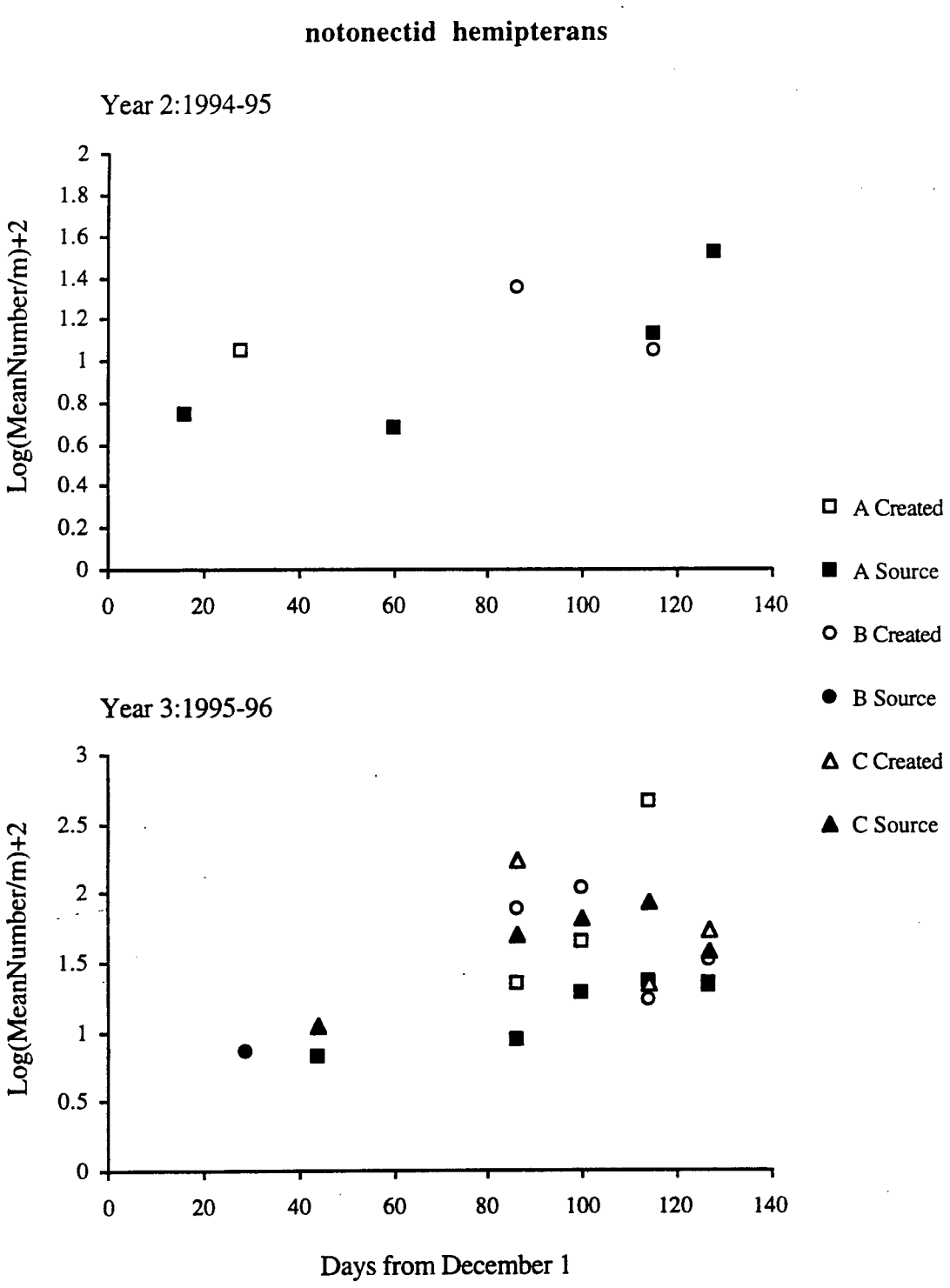

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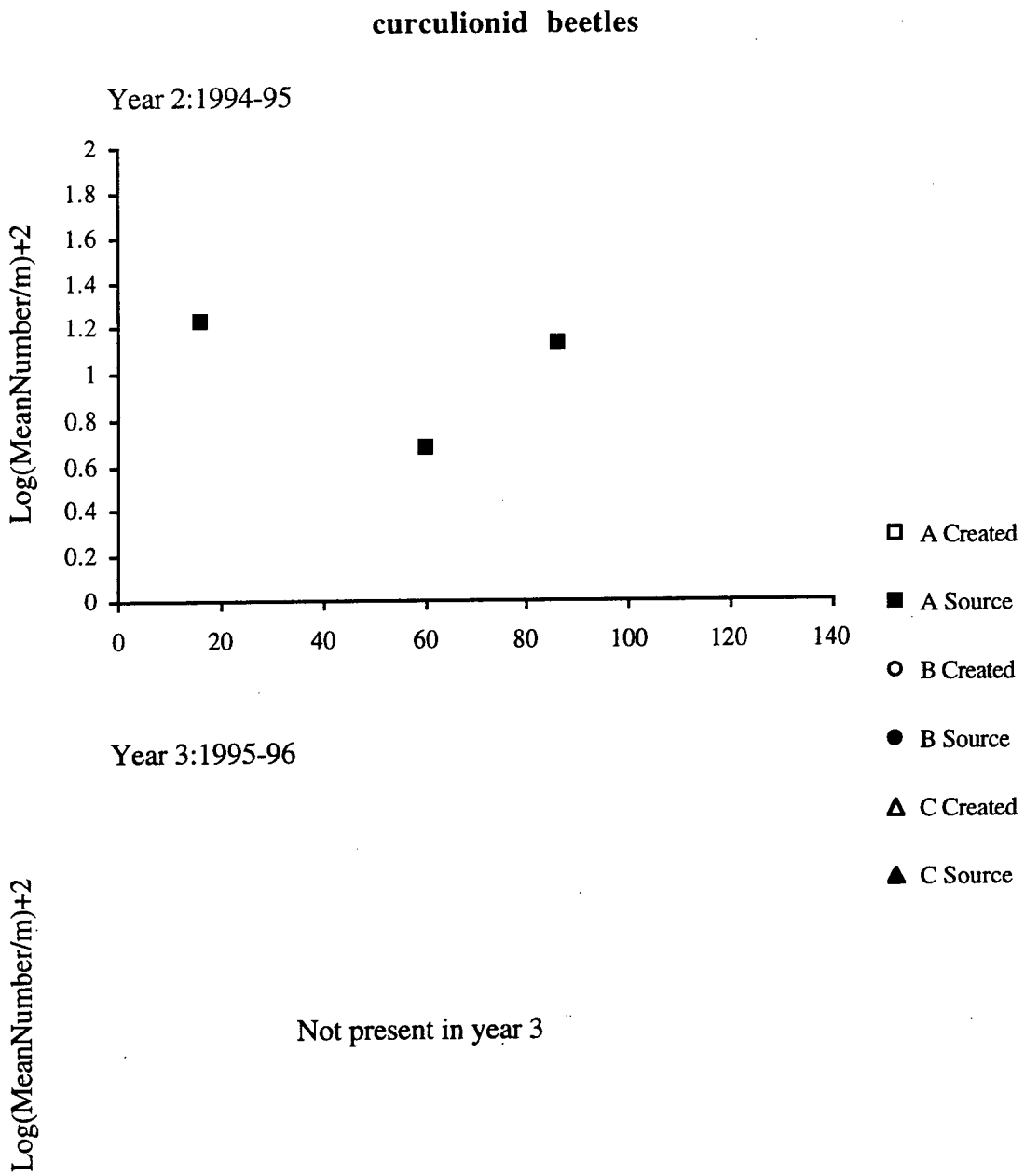

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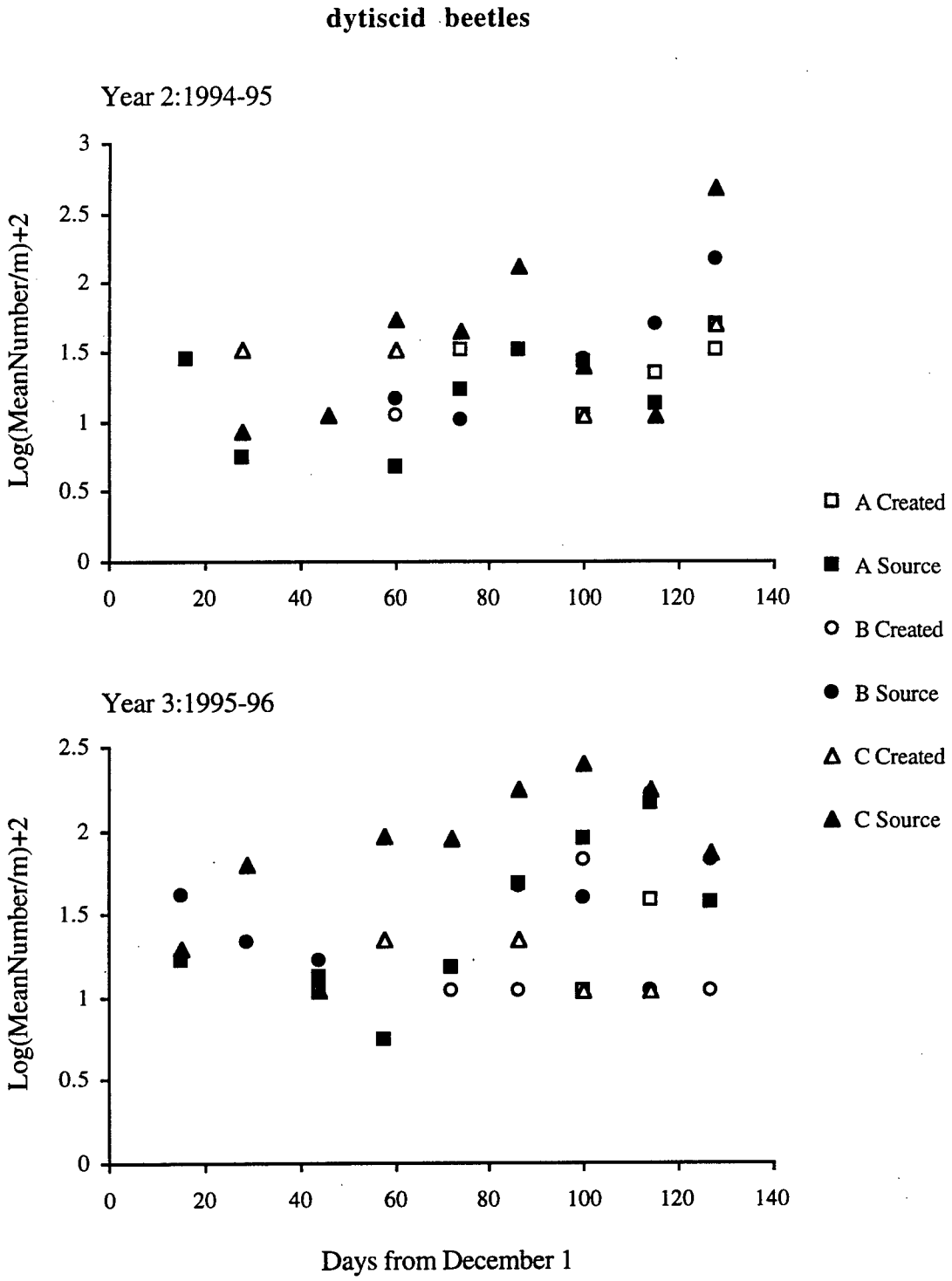

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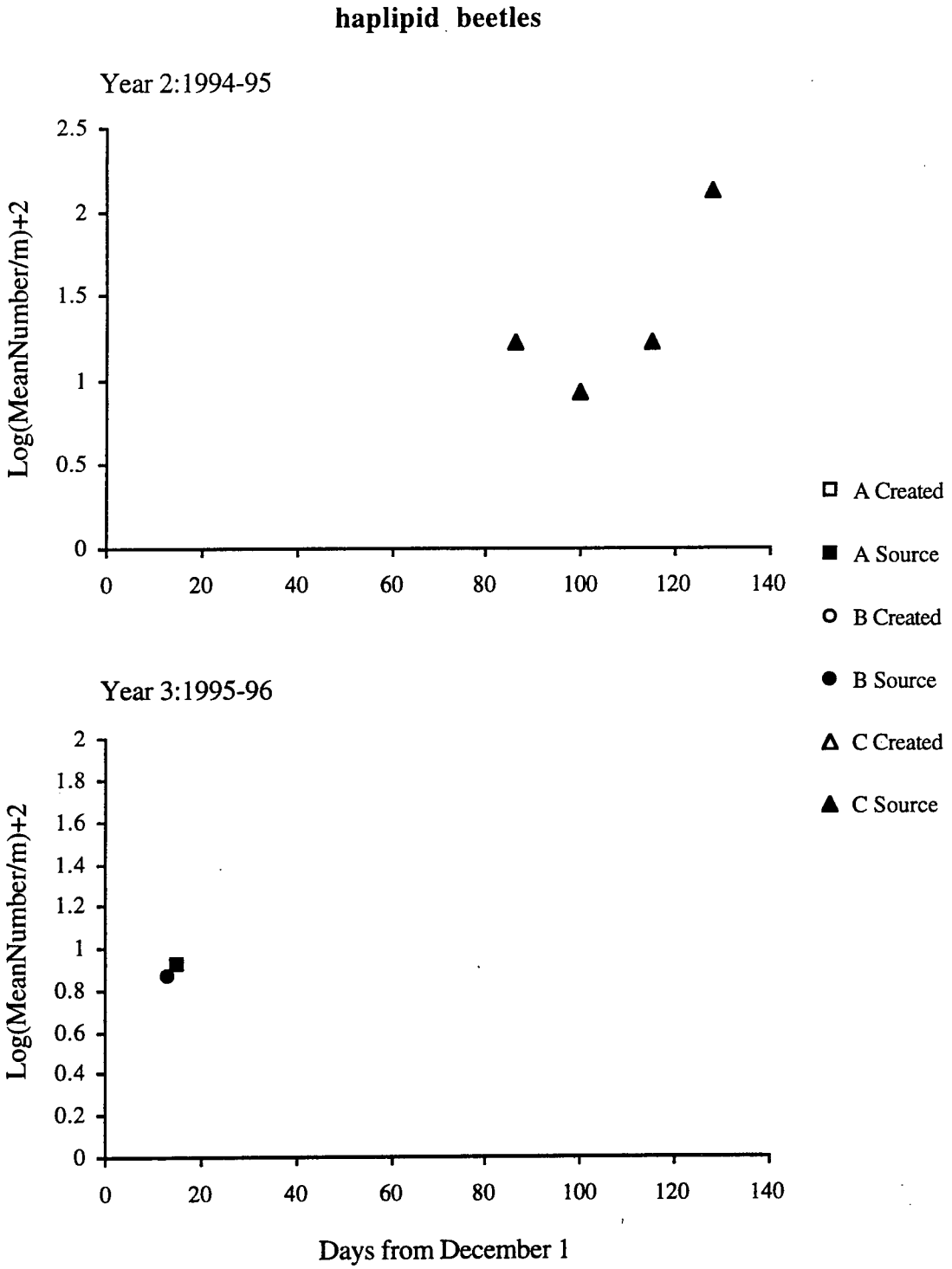

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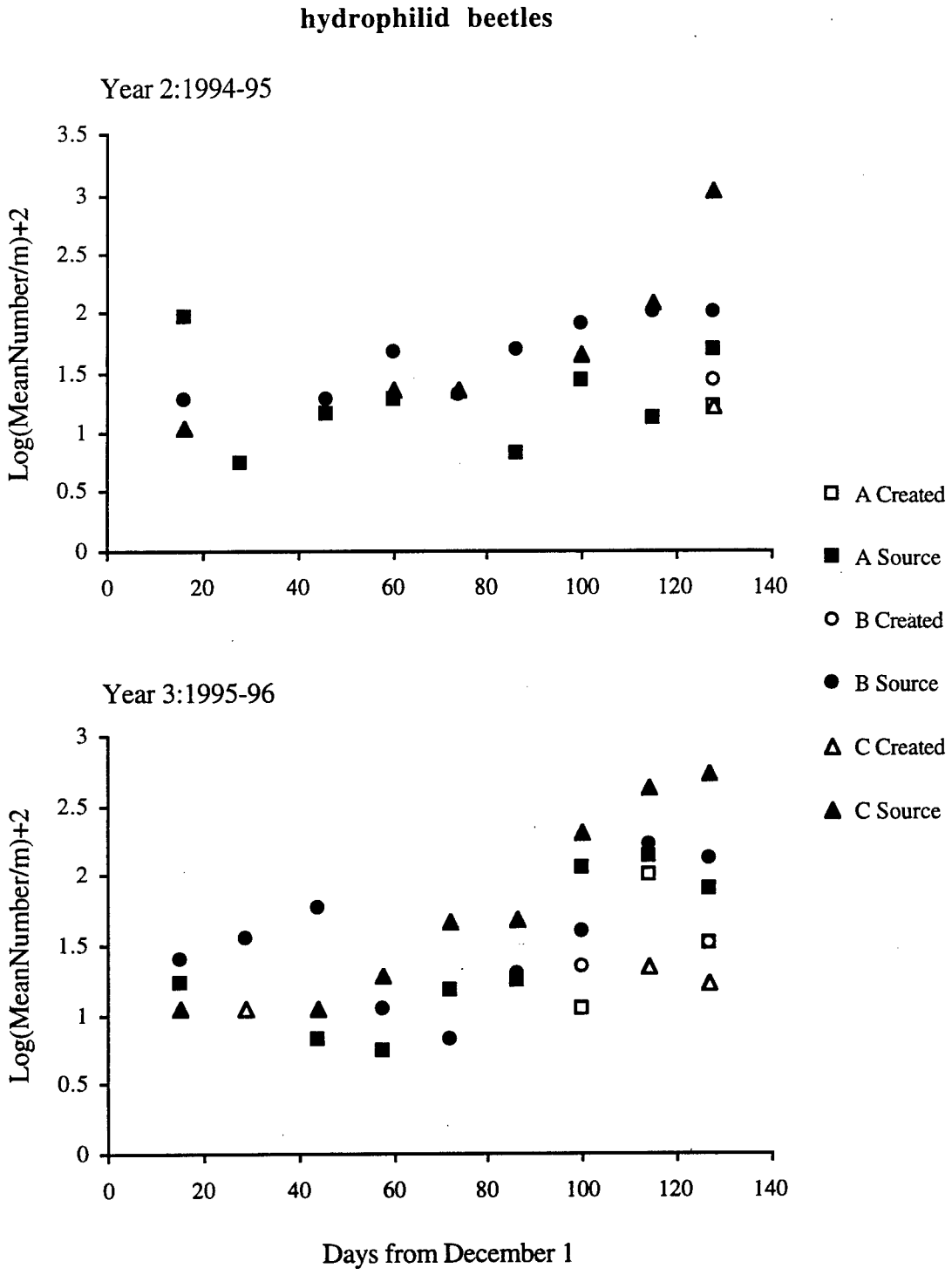

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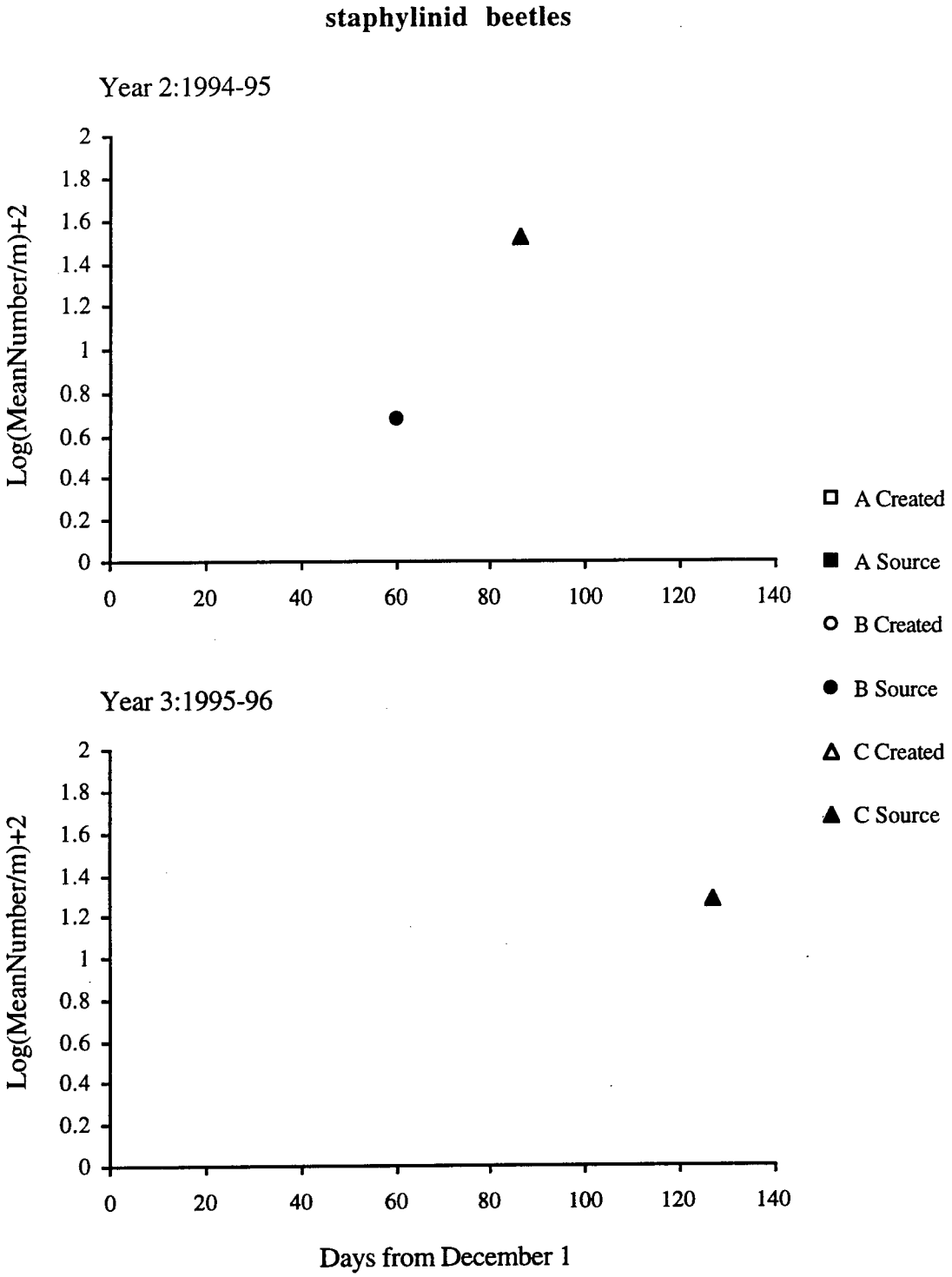

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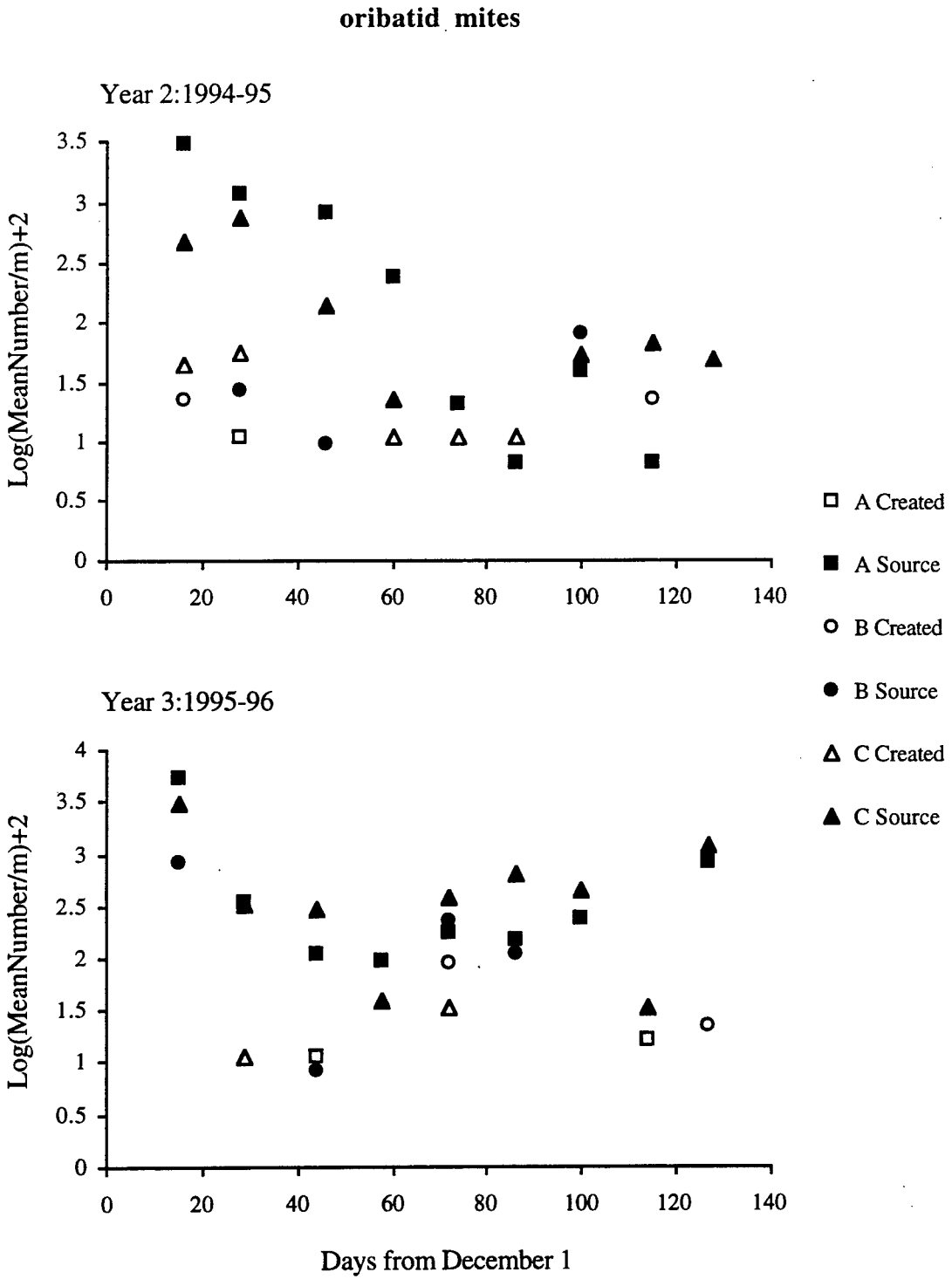

Figure D1, invertebrate trends, continued.