Moro Cojo Slough NPS Implementation Project

Final Report
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Submitted to the Central Coast Regional Water Quality Control Board

By

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## Executive Summary

Early in the twentieth century the Moro Cojo Slough supported vast expanses of freshwater wetlands that supported a rich community of wildlife, filtered sediments from the water, and acted as a sponge keeping the water from flowing off the land, preventing erosion, reducing the threat of flood, and recharging freshwater aquifers. Sixty to seventy years ago, these wetlands were drained. The land was dried, the waterways were constrained in a ditch system and the former floodplain was turned to agriculture and rangeland.

Today the Moro Cojo Slough watershed, like most of California's watersheds, is highly degraded. Only small remnants of the freshwater wetlands remain. Water runs off the uplands into denuded seasonal creeks, carving deep gouges in the landscape. Loads of chemical pollutants and sediments are picked up and then deposited downstream. Water quality doesn't exist.

Fortunately, unlike much of the former wet corridors in California, there is enormous potential to restore the vast majority of this watershed. The benefits derived and the potential for restoring the Moro Cojo watershed was studied at length and the Moro Cojo Slough Management and Enhancement Plan, was developed. This project is the first phase of implementing the preferred alternative identified through the planning process.

During the course of this project we worked on restoring over 350 acres of the Moro Cojo Slough watershed in order to improve water quality, reduce erosion and sedimentation, increase aquifer recharge, and recreate wildlife habitat. All within the context of active agricultural operations.

The success of this project and future restoration of the Moro Cojo watershed is the result of an extensive community of participants, that include farmers, geologist, hydrologists, biologists, chemists along with State and Federal agency representatives, Monterey County officials and managers, private landowners, and land conservancies.

## Introduction

The Moro Cojo Slough has been identified as an impaired water body and is listed as such on the current California 303d list due to problems associated with pesticides and sedimentation, and 3 TMDLs are scheduled for this watershed. High levels of nickel, dieldrin, total DDT, toxaphene, and PCBs are present in Moro Cojo Slough along with measurable levels of dacthal, endosulphan, and heptachlor epoxide. The Central Coast Regional Toxic Hot Spot Cleanup Plan identifies Moro Cojo Slough and its tributaries (Castroville Slough) as an important source of sediments and pesticides to Moss Landing Harbor, which is a State listed Toxic Hot Spot. The Toxic Hot Spot Plan Assessment of Actions required to remedy and restore Moss Landing Harbor identifies restoration of the floodplain as a means for reducing the movement of pesticide laden sediments into the Harbor. The project is Phase I of implementation of the Moro Cojo and Toxic Hot Spot Plans. By ponding water, and by restoring the native wetland vegetation we reduce the transport of sediments and pollutants to the Harbor, and we reduce the pollutant loads in these waters by restoring the natural ability of wetlands to clean water through biological and physical breakdown of pesticides and fertilizers.

Many of the problems that are now associated with most of California's waterways stem from the fact that natural watershed functions that served to maintain high water quality and wildlife - by filtering pollutants, by recharging aquifers, by providing flood storage capacity, and by providing habitat - have been disrupted. Restoration of the core of the watershed, which is realistic and immediately obtainable along most of the Moro Cojo Slough watershed, has proven to be one of the most technically and scientifically sound, and cost effective means for solving many of these problems, simply by restoring the natural function of wetlands. By impounding water that is now allowed to flow off the land into the ocean, we will allow it to percolate into the substrate and eventually the aquifers, reversing a 50-year trend of sea water intrusion into the coastal aquifers. Even the most persistent pesticides such as DDT breakdown more rapidly in shallow ponds, simply due to exposure to sunlight. Ponds allow for the finest sedimentary particles (which transport pesticides, metals, and other pollutants) to settle out of the water column, preventing the concentration of these materials at single locations such as the Moss Landing Harbor. Restored wetland vegetation cleans water by removing nutrients. Microbial processes in wetland substrates breakdown nitrates into harmless forms of nitrogen through denitrification.

We have made considerable progress towards achieving the goal of restoring the entire watershed. Achievements that include restoration of large areas of the Moro Cojo Slough watershed, involvement of the local scientific and farming communities, and technical advancements in the development of effective strategies.

## Acknowledgements

We would like to thank Amanda Bern, Ross Clarke, Kristy Uschyk, Peter Slattery, Sue Shaw, Tereza Jezkova, Dr. Fred Watson, Dr. Suzy Worcester, Dr. Doug Smith, Dr. Swarup Wood, Bruce Delgado, Rick Fournier, Tricia Lowe, Lou Calcagno, Curtis Weeks, Bryan Largay, Joy Larson, Dr. John Oliver, Elio Rodoni, and Hugo Tottino. The input that each of these people has provided has guided this process and we credit each of them with the success of this project. We would also like to thank the CEC crew for their enthusiasm, wonder, and lots of hard work.

## Tasks

### Task 1 Project Management and Administration

Project management and administration include coordination of all the tasks completed during the project period. The initial Project Director accepted a position with another restoration group. In September 2001, Dr. Robert Burton was appointed by CEC as the new Project Director. The Regional Water Board was formally notified as specified in the contract.

Beginning December 2001, project management and administration included completion of Phase I Design Plan for the Moro Cojo parcels, quarterly documentation of all restoration activities, writing the quarterly reports, compilation and organization of all monitoring data, obtaining photographs of the restoration sites, data analysis and completion of this final report.

### Task 2 CEQA/NEPA Documents and Permits

No work subject to CEQA was performed during the course of this project.

### Task 3 Technical Advisory Committee (TAC)

A Technical Advisory Committee was formed in May 2001 and the first TAC meeting was held June 28th, 2001 (see Appendix A for attendance list, agenda, and minutes from first meeting as well as list of all TAC members). The first meeting served as an introduction to the work plan as well as an opportunity to get TAC input on the design plan for the 200 acre Moro Cojo site (formerly referred to as Catellus parcel) and the Tottino Ponds site (Figure 1).

In September of 2001, The TAC visited two restoration sites. The first site, Tottino Ponds, is a freshwater wetland created, with reclaimed water, in a former branch of the Castroville Slough. The ponds serve as an excellent example of how quickly restored wetlands can be colonized by invertebrates, providing valuable feeding and nesting areas for shorebirds and waterfowl. The Tottino Ponds also serve as a model for working with farmers to prevent flooding of agricultural fields and farm roads adjacent to restoration sites.

The TAC was not re-convened as a whole group at the end of the project period because nearly half of the original members were no longer available. All members of the TAC that were still available were taken on tours of the restoration sites during 2003 and were involved in discussions of future projects and design plans (Table 1). For the future, the TAC will be re-structured to include a broader base of participants and will be convened on a bi-annual basis to discuss the ongoing work to restore the Moro Cojo and Castroville Slough watersheds.

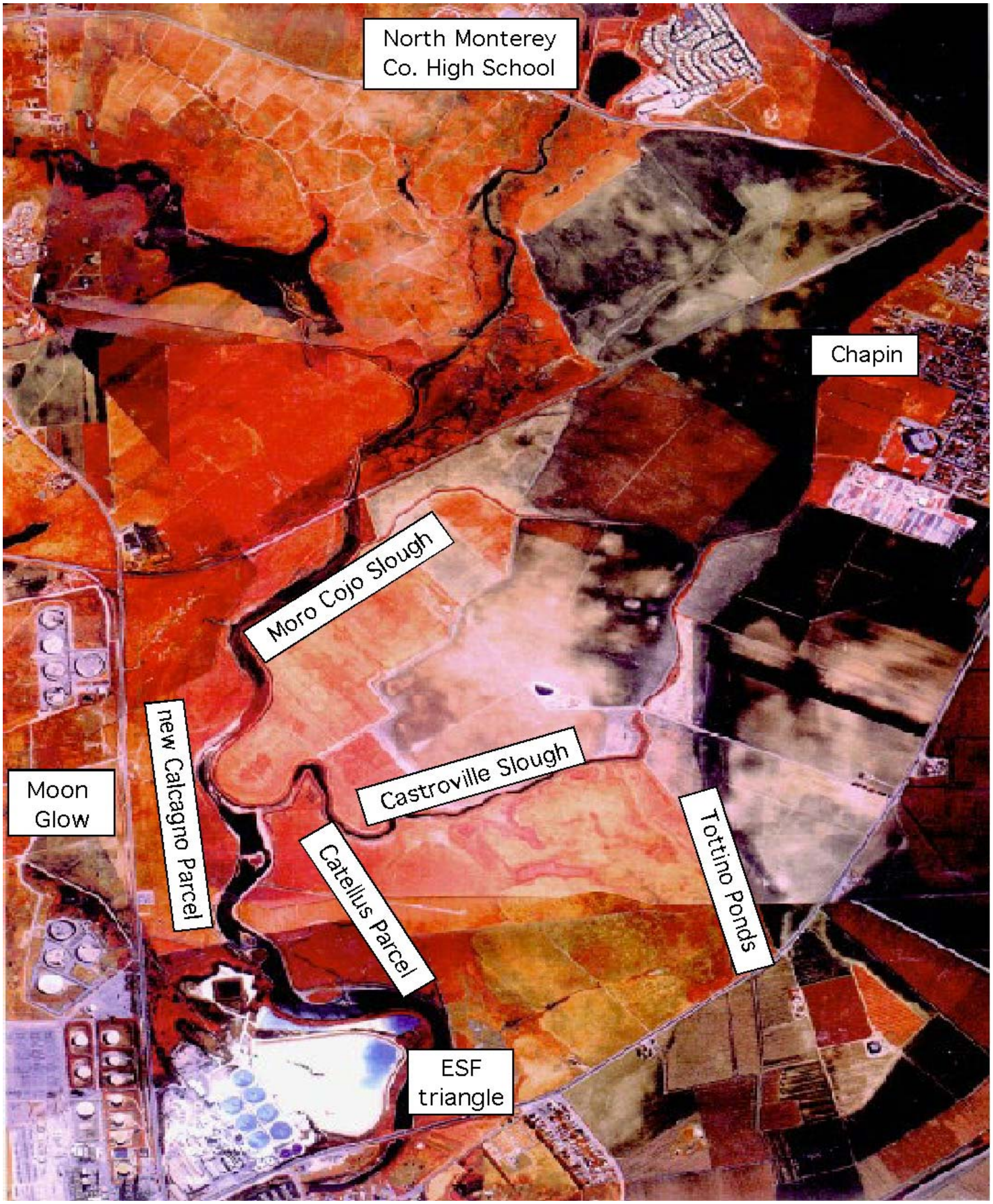



Figure 1. Locations of restoration sites along the Moro Cojo Slough.

Table 1 – Original Technical Advisory Committee members and list of TAC members who visited the site in 2003, and/or new members representative of the agencies involved in the original TAC.

| **Original TAC Members** | **Current TAC Members who visited restoration sites** |
|---|---|
| Dr. Doug Smith, The Watershed Institute | Dr. Doug Smith, Dr. Suzy Worcester, & Dr. Fred Watson, The Watershed Institute |
| Manuel Saavedra, Engineer, Monterey County Water Resources Agency | Curtis Weeks, General Manager, Monterey County Water Resources Agency |
| Mark Silberstein, Jane Holte, Elkhorn Slough Foundation | Mark Silberstein, Kim Hayes, Elkhorn Slough Foundation |
| Amanda Bern, Central Coast Regional Water Quality Control Board | Amanda Bern, Central Coast Regional Water Quality Control Board |
| Peter Slattery, John Oliver, Robert Burton, Moss Landing Marine Laboratory | Peter Slattery, Robert Burton, Moss Landing Marine Laboratory |
| Karen Christiansen, Brian Largay, Santa Cruz County Resource Conservation District | Brian Largay, Monterey County Resource Conservation District |
| Ross Clark, California Coastal Commission | Ross Clark, California Coastal Commission |
| Ron Stefani, North Monterey County Parks and Recreation | Not Available |
| Louis Calcagno, Supervisor Monterey County | Louis Calcagno, Supervisor Monterey County |
| Patsy Heasly, California State Coastal Conservancy | Did not visit site, contacted by telephone. |
| Kevan Urquhart and Patricia Anderson, California Department of Fish and Game | Not contacted in time for this report. |

**Task 4 Quality Assurance Project Plan**

By July 2001, a Quality Assurance Project Plan (QAPP) was prepared and maintained in accordance with the US Environmental Protection Agency's Interim Guidelines and Specifications for Preparing Quality Assurance Project Plans (EPA QA/R-5 1994). The title of the QAPP is Comprehensive Watershed Management Solution to Nonpoint Source Pollution in Salinas Valley. As per instructions from Alison Jones, changes to the QAPP (e.g. new sampling locations and equipment) were submitted to the contract manager as an amendment to the original QAPP prior to taking water quality samples.

After observing the flow of irrigation water and rainwater we identified alternate sampling stations that would provide more quantitative data on the impacts of vegetative and hydrologic restoration on water quality. These water quality sampling stations at the Moro Cojo floodplain site were identified in the December 2001 Quarterly Report.

**Task 5 Restoration Implementation**

The following sections document the implementation of this restoration project at five locations along the Moro Cojo Slough watershed (Figure 1). The original contract called for working to restore a minimum of 5 sites covering 200 acres of the Moro Cojo Slough watershed, in terms of acreage worked on we have exceeded that original goal by more than 50% of the original agreement. The sites are listed in Table 2.

Table 2. Restoration sites and acreage worked on during the course of this project.

| Site | Site Name | Area of the site |
|---|---|---|
| 1 | Moro Cojo Floodplain* | 196 acres |
| 2 | Tottino Ponds | 14 acres |
| 3 | New Calcagno site | 12 acres |
| 4 | North Monterey County High | 100 acres |
| 5 | Moon Glow Dairy | 10 acres |
| | Total Acreage | 332 acres |

* - This site was formerly referred to as the Catellus parcel

Landowner Participation

Landowner participation included interactions with and the participation of the persons or groups who own or manage the restorations sites, as well as with persons or groups who own and/or operate on adjacent lands. The primary goals of these interactions are to ensure that landowners are involved in the restoration design and implementation process, and to ensure that the restoration activity and their decided use of their lands, compliment each other. Please refer to Figure 1, for locations of the restoration sites discussed in the following sections.

*Landowner Participation: Tottino Ponds and Moro Cojo floodplain site (Catellus)*

One of the major concerns of farmers is that the restoration of native plant and animal communities, adjacent to their farmlands, will lead to increased damage of crops, by species that are advantaged by the restoration process. Very early on in this project we began working very closely with Sunrise and Seamist farm owners and management to identify sources of rodent pests that may originate within the restoration sites, and to identify ways where we could jointly manage both the farm and the adjacent native habitats in a manner that would stabilize unchecked rodent populations.

One of the most successful efforts we have put forth with this project is with Sunrise Farms, which is bordered on the south side by the Tottino Ponds, and along the north edge by the Moro Cojo floodplain site (see Figure 1). Before we constructed the ponds and began restoration of wetlands at the Tottino Ponds site, the area had to be disced, by the farmers, multiple times during the year to eliminate a standing crop of weeds and to breakup mud-cracks that provided perfect cover for virtually unchecked populations of rodents. In addition, the farm edge was regularly baited with rodent poison. These tactics offered some relief from damage to crops, but for the most part the solution was short term, requiring repeated and regular treatment.

By digging and filling shallow ponds with recycled water and restoring the native vegetation, we have significantly altered the habitat, which in the past had been almost exclusively beneficial to rodents. By altering the habitat we have reduced the amount of space available to rodents and we have encouraged re-colonization of the restoration sites by a diverse community of predators. These activities significantly reduced previously unchecked rodent populations, and by working with the farmer to identify areas where rodent crop damage was focused, we have been able to dramatically reduce rodent damage to crops, and eliminate the need for the farmer to engage in management of rodent populations.

As part of the monitoring component of this project, we have conducted extensive live-trap surveys of small mammal populations in various habitats (see below) to quantify small mammal distributions and species composition. Both Sunset and Seamist Farms have participated in these surveys by allowing us to trap in the agriculture fields, by working with us to identify trapping locations, and by working with us to schedule surveys and farm operations so that these activities would not interfere with one another.

At the Moro Cojo floodplain site, the restoration has benefited many species, including Canada Geese, which can be a problem for the farmers during the early planting stages. In the spring, geese walk or fly into the farmer's reservoir early and late in the day, and often enter the adjacent brussel sprout fields to feed on young sprouts. To solve this problem we worked very closely with Sunrise Farms for the initial two months of the planting phase and ensure that we have a person on-site, while their crews are not, to discourage geese from entering the fields. This cooperative solution to the problem has resulted in very little geese related crop damage for the past two and a half years, even with the increased local presence of Canada Geese in response to the restoration.

Sunrise Farms made one of the most important contributions to the success of the restoration work at the Moro Cojo floodplain site when they provided us with access to recycled water via their irrigation pond. They allowed us to plumb a metered line to the drain of their irrigation pond. This enabled us to maintain water levels, year round, in ~10 acres of ponds and wetted areas, which we constructed. This includes a large area that we can now flood (in 2-3 inches of water) along the southeast farm edge adjacent to the Moro Cojo floodplain site, further reducing the movement of mice from the grassland areas to the farm. The use of recycled water for restoration was approved by both the Central Coast Regional Water Quality Control Board and the Monterey County Water Resources Agency (Appendix B).

Our work with Sunset farms has significantly reduced the rodent problem along the two farm edges adjacent to the restoration sites. This in itself is very important in that this is a widespread concern among farmers. We have very effectively demonstrated to the landowner and farm management that wetland restoration can be a far more efficient method for reducing rodents than more traditional approaches. This has already had some important implications beyond the boundaries of our restoration sites. The fact that we have effectively worked with Sunrise and Seamist Farms to find a solution to the rodent pest problem ameliorated concerns that Seamist Farms expressed concerning the sale of a large watershed parcel to the Elkhorn Slough Foundation. A sight that will be restored under Phase II of the Moro Cojo Restoration Project.

Possibly even more important is that our demonstration that wetland restoration can be a far more efficient method for reducing rodents than more traditional approaches, has led the landowners and farm management of Sunset and Seamist Farms to communicate this fact to other landowners. An important step towards increasing landowner participation in the management of these watersheds.

*Landowner Participation: Moon Glow Dairy*

Mr. Calcagno, owner of Moon Glow Dairy, purchased approximately 65 acres of pasture adjacent to Moro Cojo Slough immediately north of the Moro Cojo floodplain site (Figure 1), which we refer to as the New Calcagno Site. Almost half of the site was covered with historical wetlands that were dried for crops and cattle grazing many decades ago. Mr. Calcagno grazes the portions of the property but far less intensively than the previous owner did. Mr. Calcagno was very interested in restoring freshwater wetlands that he knew from personal experience existed there several decades ago. The success of our work on the Moon Glow Marsh restoration was essential to Mr. Calcagno's decision to include this new site in the ongoing restoration of the Moro Cojo Slough watershed.

We worked with Moon Glow Dairy to develop a plan to exclude cattle from low areas and swales adjoining the slough. Moon Glow Dairy crews built a fence along the top of the slope leading to Moro Cojo Slough. Cattle are now excluded from this relatively steep slope, which if over grazed or trampled would create a serious erosion problem. We then planted native trees, perennial shrubs and grasses during the winter of 2001 to stabilize the steeply sloped bank along the slough edge. Mr. Calcagno's assistance and willingness to exclude cattle from the slope, provided protection from grazing of the existing native plants, and the perennials we planted. The vegetation has recovered considerably and there is virtually no evidence of erosion off this slope into the main channel of Moro Cojo Slough.

We have an unusual opportunity as far as landowner participation, in that North Monterey County High School, which is the primary focus of our education and outreach efforts, is also one of the large landowners in the Moro Cojo watershed. Over the course of this project, we have worked very closely with faculty, students, and administrators of North Monterey County High School to restore and maintain the large wetlands and uplands adjacent to the school grounds. This has involved development of a greenhouse program where students plant local stocks, nurture the greenhouse plants, and outplant these into the adjacent restoration site. We have developed a demonstration garden near the school building with all native plants, which very likely occurred at the site in the past. This is has been a great success, with a lot of interest from other members of the faculty and administration. In fact, at the end of this project we began to develop a second demonstration garden on the school grounds.

Finally, we have worked with two small-scale landowners in the upper watershed to advise and assist them with implementation of restoration projects on their lands, both of which include seasonal creeks that drain into the Moro Cojo Slough. Both of these sites had long been denuded of native vegetation and then largely overtaken by weeds. One landowner is implementing a restoration project on their 3-acre parcel that includes a pond and seasonal creek, which are surrounded by ~ 3 acres of formerly grazed upland riparian corridor. This site is particularly key because it is immediately downstream from a restoration site we implemented in the past. Another landowner is beginning to replace non-native plants with native species in a second seasonal creek. With both of these landowners we have assisted them with developing design plans and we have provided them with plants and assistance with planting.

Our intent in the upper watershed is to restore wetland/riparian habitat that will decrease erosion, increase recharge, and provide wildlife habitat. Many of the residential properties in the upper watershed have seasonal creeks where the riparian habitat has long been removed or disrupted. Residential area projects like the two we are working with landowners on, can have a very important positive impact as demonstration projects because they significantly improve the quality of the residential setting, and neighbors take notice. In fact one of the new landowner's interest in restoring the parcel is the direct result of their introduction to one of our demonstration restoration site. This provides a very clear example of the positive benefits of well-placed demonstration sites. An important part of the continued expansion of this restoration program to other key sites in the Moro Cojo Slough is our continued ability to demonstrate successful sites restored in the context of a multi-use setting.

Design Plans

Early in the project period, after extensive surveys of the Moro Cojo floodplain site vegetation, wildlife, and hydrology we developed Phase I of the design plan for implementing the restoration of wetlands and native vegetation to the site. This design plan very closely conforms to the Moro Cojo Management and Restoration Plan. Specifically, the design plan incorporates the following goals and objectives of the preferred alternative of the Moro Cojo plan (see preferred alternative Appendix C):

1) Retain saltwater and freshwater habitats in the lower slough.
2) Maintain and create habitat for rare and endangered species.
3) Utilize recycled water to build wetlands and recharge aquifers.
4) Create freshwater conditions in the lower slough.
5) Retain water in the lower slough through creation of freshwater impoundments.
6) Maximize freshwater in lower slough through increased runoff and use of reclaimed water.
7) Utilize eco-engineering.
8) Implement maintenance and monitoring.
9) Create buffers between wetlands and adjacent land use.

The Design plan created for this project was identified as Phase I of the Moro Cojo Implementation Project. This allowed us to begin implementation of the Moro Cojo Plan, without having access (during the course of this project) to all of the parcels of land that are addressed in the watershed management plan. This is very important because the implementation of future phases depends on the success, particularly in the minds of the farmers, on the implementation of the initial phase. Acquisition of watershed lands in the future will be in part dependant on our demonstrating that restoration is compatible and even beneficial to the adjacent agricultural operations.

The Moro Cojo Management and Enhancement Plan calls for decommissioning the ditch and dike system that currently constrains Castroville Slough so that runoff can be captured in impoundments excavated on the former floodplain. After accessing the hydrologic, biologic, and geomorphic characteristics of the Moro Cojo floodplain sites, we decided that by impounding water from the existing ditch system on that parcel, we could create new wetland habitats which would improve water quality, capture large quantities of runoff that would percolate into the groundwater, and would enable us to refine future plans for opening the main channel to the former floodplain.

The Phase I plan also directly addresses concerns of the neighboring farmer that restoration activities may displace rodent populations into his crop, where they can impose considerable damage. Much of the focus of Phase I was to convert areas dominated by non-native invasive plants, which benefit large populations of rodents and don't support many native predators, to diverse native plant communities. The plan focused on managing the shared boundary of the Moro Cojo floodplain site and the farm. Management measures that included reducing rodent populations, controlling weeds, restoring native plant communities, decommissioning the existing ditch system, and public education.

We completed Phase I of the Design Plan and submitted the plan to the Project manager at the Central Coast Regional Water Quality Control Board and to the Elkhorn Slough Foundation (one of the property owners) in the Fall of 2001.

## Landform Change

### *Landform Change: Moro Cojo floodplain site*

The rainfall in December of 2001 allowed us to observe and document water flow patterns at the Moro Cojo floodplain site and this enabled us to refine our understanding of how the parcel had been drained in the past. There were basically two major flow patterns, which allowed water to drain from the property into Moro Cojo Slough. Water drained from the western and southwestern edge of the parcel and the adjacent farmlands through the grasses or ditches ultimately pouring into the main ditch that borders the parcel. Water also drained from the eastern and southeastern side of the parcel along the ditches, flowing north over the parcel, or along the ditch that follows the eastern edge of the parcel where they are joined by runoff from the adjacent farms and the Tottino Ponds restoration site. At that time all of the runoff drained into the Moro Cojo Slough through a breach in the dike at the center of the north side of the parcel (Figure 2).

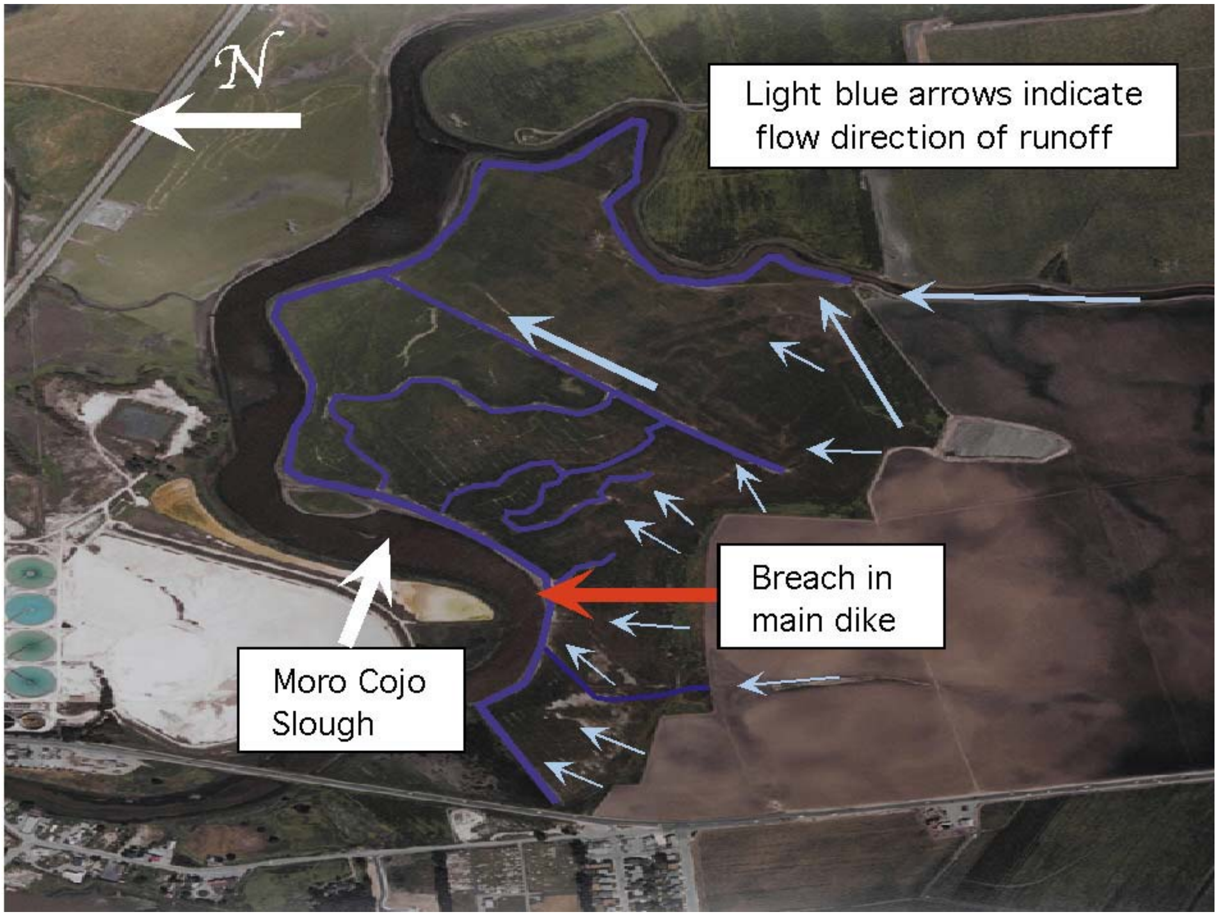


Figure 2. Flow of runoff over the Moro Cojo floodplain and location of breach in the main dike that allowed water to flow into the main channel of Moro Cojo Slough.

One of the most important landform changes we made during the initial phase of this project was the repair of the dike that isolated the ditch system from the main channel of the Moro Cojo Slough. This allowed us to impound virtually all of the water that flowed from the parcel itself, from the adjacent 200-acre farm to the south, and from the Tottino Ponds site. With the water on the site successfully retained in the ditch system we then identified areas where small earthen dams could be used to further decommission the ditch system and divert water into natural and excavated impoundments. First we blocked the large ditch that formerly drained the western side of the site forming two seasonal ponds, which formed over 6 acres of seasonally wet areas (Figure 3; Ponds A & B).

Figure 3. Ponds A and B, created by decommissioning ditches once used to drain the Moro Cojo Floodplain.

The next important landform changes made at the Moro Coho floodplain site were the repair of two man-made ponds, which had been created by duck hunters sometime in the 1940s.  These ponds, originally created by building small berms (~12 inches in height), however had long been drained and overtaken by non-native grasses.  We found and repaired the places where the berms had been breached and filled the ponds with runoff from the adjacent farm (Figure 4; Ponds C & D), allowing us to then restore ~4.8 acres of wetlands in the former duck ponds.

Pond C

Pond D

Figure 4. Ponds C and D created by repairing old dikes and filling with runoff and recycled from the adjacent farm.

During the fall of 2002 The Central Coast Regional Water Quality Control Board and the Monterey County Water Resources Agency gave us permission to use recycled water to augment winter rain and runoff (Appendix B). The neighboring farmer provided us access to the recycled water via a gravity feed 3-inch pipe plumbed to the main drainpipe of the irrigation pond. This provided ready access to water, independent of the farming operations, however not having a source of pressurized water somewhat limited our ability to move water around the entire site.

Nonetheless by using the natural gradients of the land we identified areas where shallow ponds could be excavated and flooded with recycled water that would also naturally fill under winter rain conditions. The first pond was excavated immediately west of Pond C. The location and dimensions of this pond (Pond E) were actually determined by the overflow from Pond C. The elevation of the connection between these ponds was such that the new pond (Figure 5) could be filled by bringing the water level up in Pond C, and would remained full even when we allowed the water level in Pond C to fall. Water from Pond E, then flowed north and we identified another area where an impoundment basin (Pond F) could be excavated, again by using the pattern of overflow (Figure 5). The total area covered by ponds E & F is over 2.0 acres.

The ponds we excavated are shallow, having a saucer shaped bathymetry with a maximum depth of 1 - 2 feet. Most of the ponds hold water at a depth of 12 – 14 inches. Before the ponds were excavated, Fish and Game Natural Diversity DataBase records were reviewed as were all available biological and botanical data collected at the site. The sites were also surveyed during the appropriate seasons to ensure that no sensitive species would be impacted, and to ensure native vegetation would not be impacted.

At this point we had successfully constructed impoundments that were able to capture runoff from the immediate farmlands, and from rainfall on these portions of the Moro Cojo floodplain site. Large quantities of water were still flowing down the perimeter ditch along the east edge of the site. Water that was runoff from the adjacent 200-acre farm, the Tottino Ponds area, and from some of the farm lands adjacent to that site. This water was contained in the ditch system, but the narrow, deep nature of these channels provided limited habitat value, and little potential for photo-degradation of chemical components that are present in the water.

Pond E

Pond F

Figure 5. Ponds E and F created by excavating shallow basins in the non-native grasslands and filling with overflow recycled water from Pond C.

The resolve this problem we excavated a large shallow impoundment (Pond G), among the non-native grasses on the northwest portion of the site (Figure 6). This impoundment covered an area of ~4.8 acres. Much of the overburden from the excavation was used to create islands in the middle of the pond, which could provide safe nesting habitat for birds such as Canada Geese, and many species of ducks.

We then decommissioned the perimeter ditch with a small earthen dam, and excavated a narrow channel connecting the ditch to Pond G. During large rainstorms (more than ~3 inches), water backs up behind this ditch to the property's southeast corner creating sufficient head so that it flows into Pond G. During a rain event of this magnitude the entire pond can be filled to a depth of ~12 inches, and this water is unable to return to the ditch system. On the west edge of Pond G, we decommissioned the main central ditch in the same manner. We then cut a small channel (24" inches wide) between Pond F and the main central ditch, so that water can flow out of Pond F, through the channel, into the main central ditch and then into Pond G.

Pond G

Figure 6. Pond G created by excavating a shallow basin and then filling with winter runoff diverted from the perimeter ditch system. Excavated dirt was used to create islands for nesting birds.

The diversion dam in the perimeter ditch created a large impoundment that extends from the dam to the southeast corner of the property, this 1.8-acre pond (Pond H) remains filled during the rainy months (Figure 7).  The over flow from Pond H flows directly into Pond G.  Ponds G and H capture virtually all of the runoff of ~300 acres of farmland, preventing this water from leaking into the main channel of Moro Cojo Slough.

Pond H

Figure 7.  Pond H created with a diversion dam in the perimeter ditch system and filled with winter runoff from ~ 300 acres of farmland.

Finally we created 2 small ponds to catch the overflow from ponds A and C. We excavated a small linear pond in a low area on the west half of the site to catch overflow from Pond A. This impoundment (Pond I) is about 0.3 acres in size, with a maximum depth of 12 – 18 inches (Figure 8).  This pond was excavated in an area that was dominated by a hemlock, radish, and curly dock stand that reached heights of more than 4 feet.  The site around this pond is now almost completely dominated by native plants including several vernal pool species never before recorded at this site.

During the winter months the farmer now opens the irrigation pond drain to ensure that heavy rains don't result in the irrigation pond overflowing the berm.  To handle this additional amount of runoff we excavated an additional pond (Pond J) north of Pond C to catch overflow from Pond C and the farm irrigation pond (Figure 8).  Pond J covers ~1.1 acres with a maximum depth of 12-14 inches.

Pond I

Pond J

Figure 8. Ponds I and J created by excavating shallow basins in the non-native grasslands. Pond I is filled with winter runoff, while Pond I is filled with runoff or recycled water from Pond C.

We also decommissioned numerous small-scale ditches that had been formerly used to drain smaller sections of the site. These required only a shovel but added significant areas of impounded water. During the winter rains we successfully impounded water over an additional 2 acres of the site by building these small dams and blocking the drainages, and vast areas of the site remained covered in 2-3 inches of water for long periods of time (Figure 9).

Figure 9. Large expanses of the grasslands retained water for long periods of time due to decommissioning of minor ditches formerly used to drain the site.

To date we have created 10 freshwater impoundments, totaling more than 22 acres, by excavating shallow basins or by repairing existing dikes. Of the 10 we can maintain 5 as year-round wetlands with recycled water, gravity fed through a 3-inch pipe plumbed to the main drain of the adjacent farms irrigation pond. We created an additional 7 freshwater impoundments, totaling more than 7.5 acres, by decommissioning the ditch system that had long been used to drain the site (Table 3).

Table 3. Freshwater impoundments created at the Moro Cojo restoration site.

| **Excavated or Constructed Water Impoundments** | | |
|---|---|---|
| **Pond** | **GPS Area** | **Description** |
| A | 2.904 | Winter Pond |
| B | 3.076 | Winter Pond |
| C | 2.612 | Permanent Pond |
| D | 2.165 | Permanent Pond |
| E | 1.053 | Permanent Pond |
| F | 0.866 | Permanent Pond |
| G | 5.520 | Winter Pond |
| H | 2.511 | Winter Pond |
| I | 0.335 | Winter Pond |
| J | 1.065 | Permanent Pond |
| **Total Acreage** | **22.107** | |
| | | |
| **Ponds Created by Decommissioning Ditch System** | | |
| | | |
| K | 5.688 | Permanent Pond |
| L | 0.367 | Winter Pond |
| M | 0.102 | Winter Pond |
| N | 0.228 | Winter Pond |
| O | 0.386 | Winter Pond |
| P | 0.052 | Winter Pond |
| Q | 0.713 | Winter Pond |
| **Total** | **7.536** | |
| | | |
| **Grand Total** | **29.643** | |

We also can now capture and hold winter runoff in the perimeter and central ditch system, which formerly drained into the main channel of the Moro Cojo Slough. The perimeter and central ditch system is ~10 feet wide at the top and can hold water to a depth of 3 – 4 feet (Figure 10). During a single 4" rainfall event in December of 2002 the ponds and ditch system filled completely from rainfall and runoff from the adjacent 200-acre farm, the Tottino Ponds restoration site and ~100 acres of farmland adjacent to the Tottino Ponds site. Based on the known area and bathymetry of the ponds we estimate we captured and held 12-13 million gallons of water in the impoundments and on-site ditch system, water which percolated into the ground over then next few months. Virtually all of the runoff from the site, the Tottino Ponds site, and ~300 acres of active farmlands, which formerly flowed into the Moro Cojo Slough and Moss Landing Harbor, is now retained at the Moro Cojo floodplain restoration site.

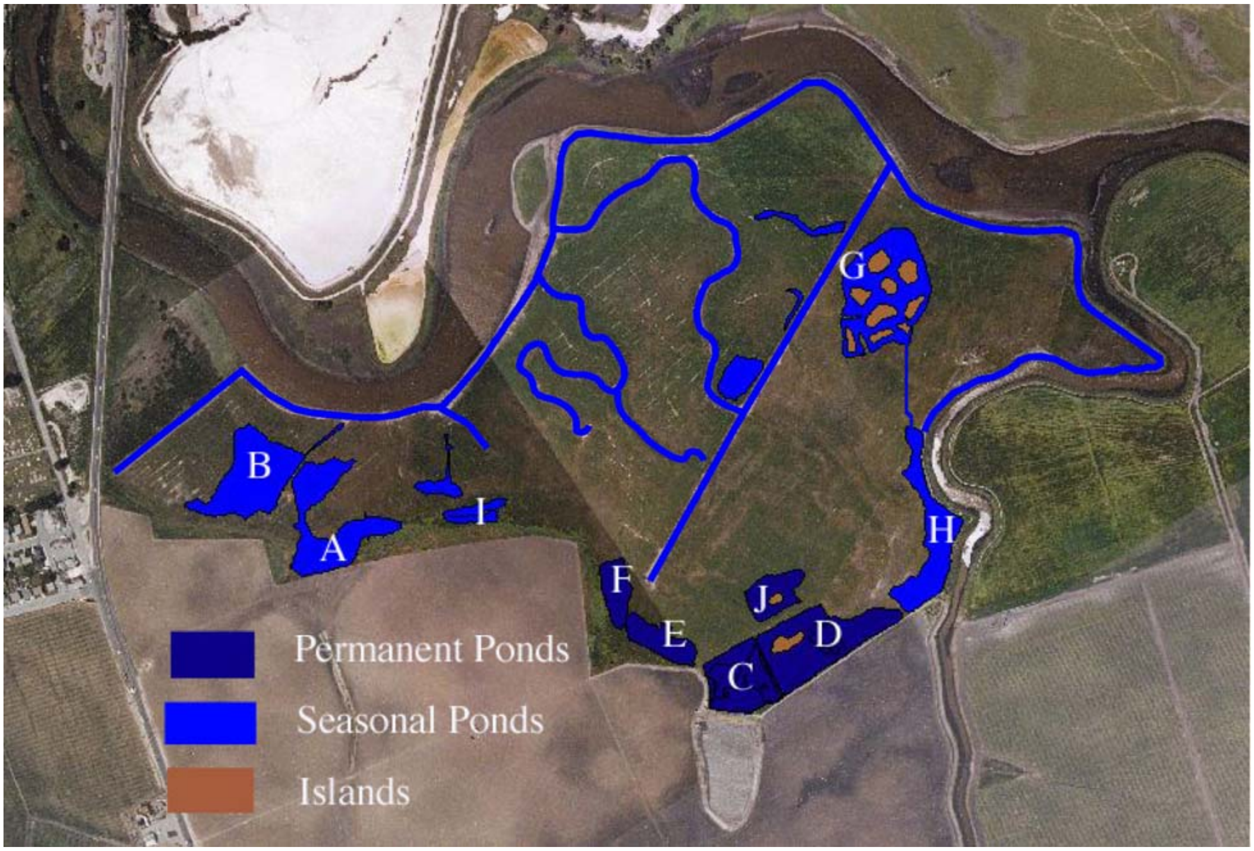


Figure 10. Freshwater impoundments created at the Moro Cojo Floodplain site showing the excavated or constructed ponds

*Landform Change: Tottino Ponds*

At the Tottino Ponds site the most significant landform change was the excavation of a sixth pond. This provided an additional 2 acres of open water and small islands surrounded by predominately native vegetation in an area that was formerly a disced barren field (Figure 11). The Tottino Ponds restoration site is just over 14 acres of which ~12 acres are permanently maintained as wetlands with recycled water.

Figure 11. Pond 6 at the Tottino Ponds restoration site created by excavating a shallow basin in an area that had formerly been a barren disced field.

We did not perform any landform changes at the other restoration sites.

Native Plant Establishment and Weed Control

Weedy species are prevalent at these sites because of a long standing cyclic pattern of disturbance and succession, which had been imposed by human activities. At some time in the past, the original native plant communities were disturbed by farming, grazing, or the construction of buildings. Then in most cases the activities that created the disturbance was ceased, leaving the space “ecologically empty”. These ecologically empty spaces were then occupied by aggressive, rapid colonizing, dense stands of non-native species that are able to out compete native species largely because they have few predators and natural competitors.

Restoration of native vegetation is an ecological process as well. The original conversion of a site from native plant communities to complete dominance by non-native weedy species is the result of ecological disturbance, extirpation of native plant and animal species, and competition with non-native plant and animal species. In the areas we worked on we were able to successfully apply these same principles in developing strategies to convert large areas dominated by weeds to sites that support diverse native plant and animal communities. This has also enabled us to develop strategies and techniques for successfully implementing restoration without the use of chemical biocides and or other artificial inputs.

*Native Plant Establishment and Weed Control: Moro Cojo Slough floodplain*

At the start of this project the Moro Cojo floodplain site, was dominated by a nearly complete cover of non-native annual barley and rye grasslands, intermixed with tens of thousands of non-native curly doc, Italian thistle, mustard, radish, and hemlock. The long history of farming and livestock grazing on this site had left only remnant stands of native vegetation. Among the more abundant native plants were salt grass, species of spike rush, frankenia, and pickleweed. Although these plants were the most abundant native species, for the most part they occupied isolated patches, most of which covered areas of only a few square meters.

As we commenced work on this site, the neighboring farmer expressed his concern that our activities would cause a mass emigration of mice from the restoration site to his cropland. To address his concern we focused the initial stage of the restoration along the shared boundary between the restoration site and the farm. The farmer suggested that when the cattle were present their grazing removed the thick cover of grasses, exposing rodents and ground squirrels to predators that maintained these populations at relatively low levels. They also suggested that with the end of grazing, there had been a considerable increase in the amount of rodent related crop damage experienced along the shared boundary. Clearly this was a problem that needed to be addressed and we did so quite successfully by incorporating this into the restoration design and implementation and we focused our initial efforts along the farm edge so that we could manage the rodent problems.

One of the most effective means for removing a standing crop of annual weeds is to mow it at specific times in the plants lifecycle, the most important of which is immediately before seed is set. This dramatically reduces the standing crop the following year, and in many cases near extirpation of non-native plant species can be achieved within a few years. Extensive mowing along the edge of the farm also removed food cover for mice and voles along the farm edge and exposed these animals to a variety of native predators, which readily took advantage of this prey base. We repeatedly mowed non-native vegetation along the entire farm/restoration site boundary to a width of up to 200 feet. This removed cover and attracted predators such as great egrets and red-tailed hawks (Figure 12). Rodent populations in the mowed areas were controlled by predators and loss of suitable habitat, and the farm saw a dramatic decline in crop damage as a result.

Mowing also had the effect of removing the standing dead biomass, which proved to be highly beneficial to some native species. By repeatedly mowing and hand weeding around the small stands of native plants we allowed these native stands to expand and dominate large areas (Figure 13). Perennial weeds require a combination of strategies that include mowing, hand pulling, and burning with a weed torch. Plants such as hemlock, thistle, mustard, radish, and many of the other broad leafed weeds along the farm edge were eliminated by repeated mowing or weed-whipping to prevent seed set for a period of ~3 years. Plants such as curly dock, which have a solid tap root show little response to mowing. Removal of curly dock with a shovel is very labor intensive, simple because they have to be removed from the ground, and disposed of or they will continue to grow and set seed. What has been successful is to wait for the plant to begin to set seed, at which time it grows an elevated seed head and the plant can be readily hand pulled. In essence we are working towards the complete extirpation of these plants by preventing reproduction. This has worked well and we've eliminated curly dock from significant portions of the Moro Cojo floodplain site.

Figure 12. Mowed area along the shared boundary of the Moro Cojo floodplain restoration site and the farm, to control weeds and rodents by removing cover and attracting predators such as these Great Egrets.

Ponding water has also proven to be a very effective means for eliminating weeds from relatively large areas, while benefiting native wetland plants that already existed in these areas. Places where water could be ponded tended to be the low lying areas on the site that had received some runoff in the past, which had maintained small pockets of native wetland plants such as the various sedges and spike rushes. By simply changing the environment, specifically the hydrologic period of the exotic grassland, we created a selective pressure that benefits native wetland species and grasses and disadvantages the weedy non-native grassland species.

We have been very successful at converting large areas dominated by non-native weeds by first disturbing the weedy plant community and then replacing these plants with early succession native plants. Essentially we are planting "successional cover crops". In wetter areas we us salt brush, which grows very well from seeds dispersed on the ground, and re-seeds quite readily. This species will also give way to longer-lived perennial shrubs and trees as these larger plants colonize or are planted into the cover crop. Salt brush has proven to be very effective at outcompeting the non-native barley and rye grasses that dominate much of the site. Once the salt brush becomes established it dominated and prevented non-native grasses from growing to maturity, exhausting the in-soil seed bank.

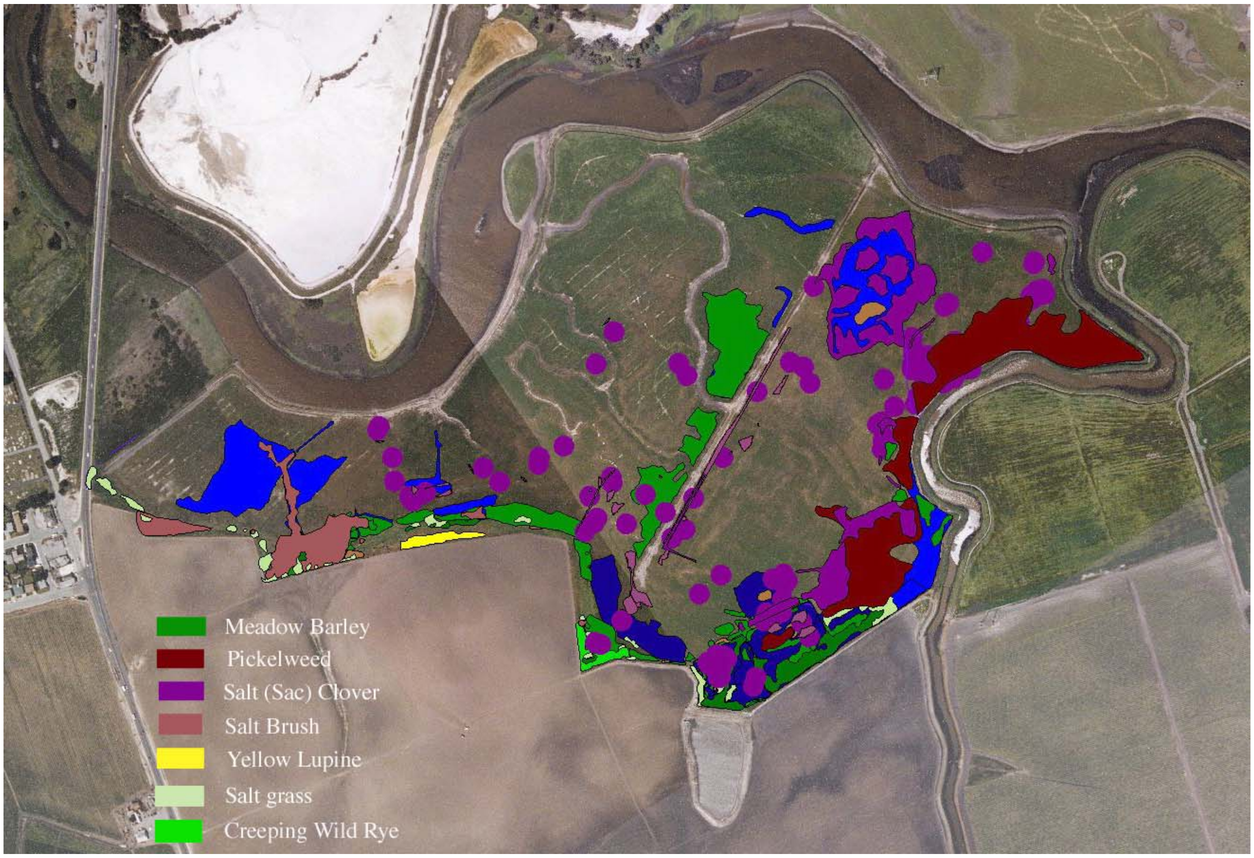


Figure 13. Native vegetation restored at the Moro Cojo Floodplain site.

In drier areas, we use relatively fast growing perennial shrubs, such as yellow lupine or coyote brush, to occupy the space. At the Moro Cojo floodplain site, the southern edge is elevated above the floodplain, and is composed of sandy soils, which are highly enriched in nitrogen and carbon leftover from thousands of years of prehistoric human inhabitation (Milliken et al. 1999). The nitrogen enriched soil proved to be ideal for broad-leafed non-native weeds, such as hemlock, mallow, brussel sprouts, mustard, and radish, which had long dominated the site. As with the salt brush, the lupines yields to other native perennials after a few years.

After repeatedly mowing the weeds that dominated the hill, we planted 1,900 fast growing yellow lupine, which were grown in our greenhouse from seeds collected on the nearby foredunes. These plants grow to 6-8 feet in diameter and the stand persists for about 3 years, during which time they dominate the site and shade out three successive generations of weeds. This created a drain on the in soil seed bank, as each successive generation sprouts but cannot mature under the dense lupine canopy and therefore cannot produce new seeds. When the yellow lupine stand began to senesce after a couple of years, other natives were planted into the stand, or in some cases simply re-colonized the site where the highly competitive weeds and grasses had been controlled.

In other areas mowing several times each year encouraged the recovery of native plant communities.  We mowed large areas covered by the Mediterranean grasses, to encourage stands of meadow barley (Figure 14) and creeping wild rye, both robust native perennial grass that add species and habitat diversity to an area and slows the proliferation of weeds.

Figure 14. Stands of native meadow barley that recovered after mowing large areas of non-native grasses, which had prevented the proliferation of native species at the Moro Cojo floodplain site.

These methods have been highly effective and have enabled us to convert large areas dominated by non-native weeds to native plant communities without the use of chemical biocides. The yellow lupine stand dominated the stand of non-native perennial weeds and the salt brush has crowded out large patches formerly dominated by non-native barley and rye.  Other more widely dispersed weeds, such as curly dock, have been controlled by hand pulling the plants ,weed whipping, or treating with a propane weed torch.

Along the edge of a floodplain, which is exactly what the Moro Cojo site was at one time, larger woody species would normally exist. We planted cottonwood, creekside dogwood, along with tule, bulrush, and willows, along the pond edges at the Moro Cojo site, which increases habitat complexity.  In fact, cottonwood/sycamore riparian habitat is the most biological diverse riparian habitat in this region (Roberson 2003).  These larger plants significantly increase the diversity of wildlife at these ponds, simply by being taller than most of the other plants, thereby providing perching, foraging, and even nesting habitat for a wide variety of birds.  These larger plants are extremely effective at long-term weed control.  These taller plants also play an important role in managing the restoration site/farm boundary in that they reduce the attractiveness of the ponds to Canada Geese. The geese prefer large open water expanses where they can see predators from the great distance and now avoid the farm edge ponds.

We have installed more than 800 willow plugs at the Moro Cojo site with marginal success at first due to inconsistent water supply and fairly high salinities in the soil. Salinity that may have been left over from a history of tiling and fertilizing the site. However, large numbers of willows cottonwoods, creekside dogwood, sycamore, and alder are now growing at the site around the permanent ponds and elevated edge of the site. In the upland drier areas we continue to expand the existing stands of creeping wild rye by transplanting plugs and by planting starts, which we propagated in the greenhouse.

One of the most spectacular successes of this restoration with regard to native vegetation pertains to a small annual native salt (or sac) clover. This species was identified as "probably extinct" in Jepson Manual: Higher Plants of California (Hickman and Jepson 1993). Approximately 50 plants were discovered near this site in the past, and the California Department of Fish and Game Natural Diversity Database reports a small patch existed on the site although we had not seen the plant at the location they identified. In 2003, this clover germinated and flowered (Figure 15) at just about every location where we had disturbed the thick thatch cover of non-native annual barley and ryegrass. Virtually everywhere we mowed, every pile of dirt excavated when the ponds were dug, and even the simple road we use, was covered with this clover. In total we mapped over 14 acres of areas completely dominated by salt clover (Figure 13). Meter quadrate surveys indicated a plant density of 15 – 25 plants per square meter. Based on this we estimate a population of 950,000 to over 1,500,000 plants germinated, flowered, and seeded, significantly recharging the standing seed bank.

Figure 15. Once thought extinct, salt clover germinated and flowered where we disturbed the dense cover of non-native grasses

All totaled we have planted over 650 trees, 1900 perennial shrubs, and 800 annual and perennial grasses and other annual and perennial herbaceous plants, and have restored native vegetation over large areas of the Moro Cojo floodplain (Table 4).

Table 4. Acreage of largest patches of native vegetation restored at the Moro Cojo site.

| Plant | Acreage Covered |
|---|---|
| Meadow Barley | 9.6 |
| Salt brush | 3.0 |
| Salt grass | 1.8 |
| Spike rushes | 2.4 |
| Creeping wild rye | 0.5 |
| Yellow lupine | 0.5 |
| Pickleweed | 9.7 |
| Salt Clover | 14.0 |
| | |
| **Total acreage** | **41.4** |

*Native Plant Establishment and Weed Control: Tottino Ponds*

We are able to closely regulate water levels at Tottino Ponds with recycled water via a pressurized 3-inch pipe that is plumbed off the purple pipe system that delivers recycled water to the farms. This has been very valuable for the eradication of weeds. When we started work on this site the area was regularly disced and supported a nearly 100% non-native stand of rip-gut brome and annual Mediterranean barley and rye. By flooding and drying the site we caused seeds left in the ground to germinate and then we re-flooded the germinating plants. By repeating this many times we were able to eliminate a well developed in ground bank of rip-gut brome seed.

At this site we had to introduce virtually all of the native plants due to the fact the site had been disced for many years for rodent control. We introduced several hundred plants and we have also had a great deal of success with broadcasting seeds of a number of late successional plants (creeping wild rye, bulrush, spike rush, iris leafed rush, hair grass, and several sedges). Initially we had difficulty with woody species such as willow, probably due to high salinities left over from agricultural runoff. After more than a year of repeated flooding willows finally became established from the several hundred starts. We also installed wind-breaks around the willows which helped significantly.

At the Tottino Ponds site we have removed most of the dominant weeds from the areas around the 6 ponds. Around the first 5 ponds this was done predominantly by mowing, weed-whipping or hand removal. At Pond 6, this was done with a combined approach of mowing with the tractor, weed whipping and hand pulling, and repeated flooding of areas dominated by weedy terrestrial plants.

The work in Pond 6 is worth a few additional comments because it is an outstanding example of adaptive management. Everything we learned from previous restorations was applied here. After the shallow pond system was excavated, non-native grass and other plants germinated and dominated the site. They were mowed, weed whipped, and hand weeded to reduce seeds, and the site was dried to kill all the remaining annual grasses (all non-natives). We broadcasted native plant seeds over the entire site, including the two most aggressive early native successional species (creeping wild-rye, and bulrush), and this community of native plants has come to dominate the site.

The different successional ages of the ponds of course led to differing strategies for modifying the hydrologic setting of each pond. Initially we piped water only to Pond 1 and then let it flow between each of the ponds, but at Pond 5 the water simply flowed into a shallow aquifer and we could not reach the Pond 6 site. To rectify this we ran a 4-inch pipe from the purple pipe main, along the ditch that runs along the south edge of the site, with valves at each pond. This enabled us to manipulate the water level in the ponds independently. This also allowed us to experiment with wet/dry regimes, water levels, invertebrate succession, and weed control.

To date we have created 12 acres of ponds with the recycled water at the Tottino Ponds site (Figure 16). The area around the ponds is restricted by the adjacent farms, nonetheless we have restored about 2 additional acres to predominately native vegetation, most of which is comprised of the same species found at the Moro Cojo floodplain site. One exception is the African brass buttons, which are a secondary or tertiary level successional weed that can be quite invasive. Nonetheless as the system matures the larger plants such as bulrush, willow, and cottonwood are clearly dominating brass buttons. Another excellent example of how we have used the ecology of these disrupted systems to convert them to native habitats, water filters, and re-charge ponds. Most important is that we have done this without the use of chemical inputs such as biocides and fertilizers.

All totaled we have planted 550 trees, and 60 shrubs at the Tottino Ponds site, and we have drill seeded or broadcast seeds across more than 12 acres of the site.

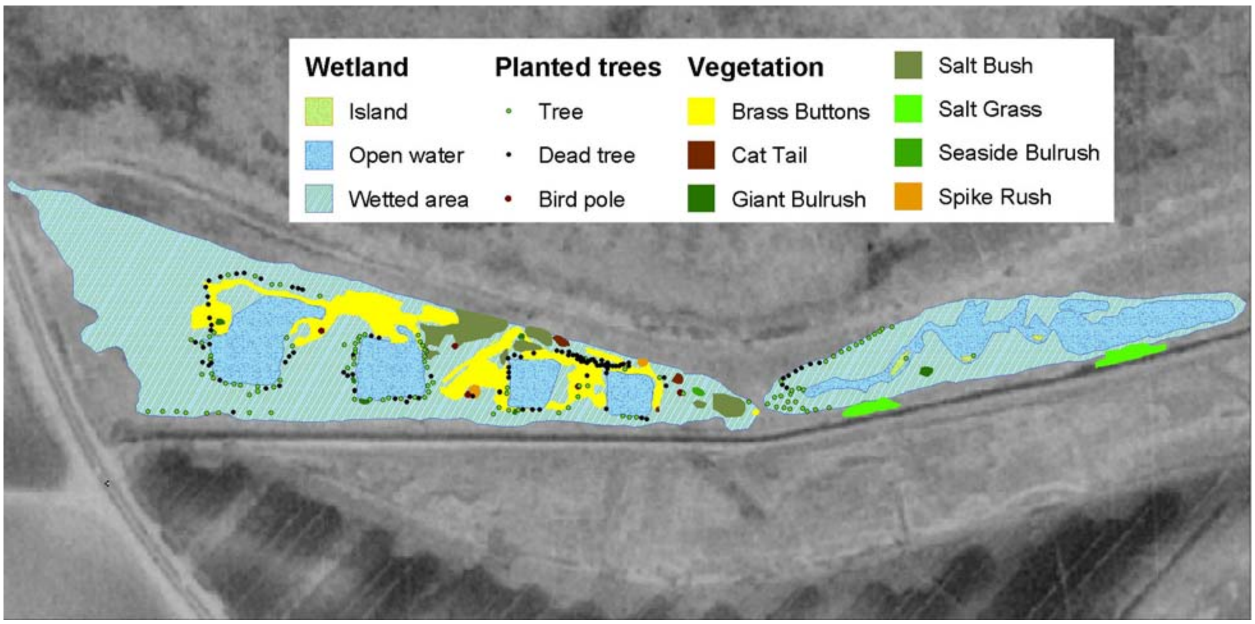


Figure 16. Wetlands and vegetation at the 14-acre Tottino Ponds Restoration site.

*Native Plant Establishment and Weed Control: Calcagno and Moon Glow Sites*

The Calcagno lands that border Moro Cojo Slough are steep in some areas and had previously been grazed. After Mr. Calcagno had a fence installed to exclude the cattle from the step slope we planted coast live oak to stabilize the hill and shade out the weeds (Figure 17). We also planted numerous species at the restoration site on the Moon Glow Dairy north of Dolan Road. We have taken a slower, yet long term approach with these sites, planting slow growing trees that do not take considerable additional energy after the first 2-3 years. All totaled we have planted more than 140 trees, 77 shrubs, and 37 annual grasses and other annual herbaceous annual and perennial plants at the Moon Glow and Calcagno sites.

Figure 17. Oak trees planted on the slope at the Calcagno site to stabilize the slope and shade out weeds along Moro Cojo Slough.

*Native Plant Establishment and Weed Control: North Monterey County High*

The wetlands at North Monterey County High (Figure 18) are now in excellent condition and are virtually weed-free.  The large upland areas between the campus and the wetlands have been dominated by non-native grasses for decades but we are converting them to native upland vegetation.  An important part of protecting the integrity of the wetlands is the elimination of sources of invasive weeds.  This has involved repeated mowing of large areas of non-native grasses and installation of native coyote brush willows and oak.  We have also established creeping wild rye, which spreads by rhizomes making it an excellent plant for stabilizing the upland slopes at that site.

We have grown several thousand plants in the high school greenhouse, primarily for outplanting at that site, and built a demonstration garden of native plants.  This has generated considerable interest and enthusiasm from the students and faculty and as noted earlier this has led to a second faculty member wanting to create a native plant demonstration garden at the school.

All totaled we have planted over 400 trees, 2080 shrubs, and 3900 annual and perennial grasses and herbaceous plants at the North Monterey County High School site.

Figure 18. Large wetland at the North Monterey County High School site.

All totaled we plant over 10,700 plants during the project period (Table 5) at 5 sites as described above.

Table 5. Number of trees, perennial shrubs, and herbaceous species planted at 6 restoration sites in the Moro Cojo Slough Watershed.

| Site Name | Trees | Perennial Shrubs | Herbaceous Species and grasses |
|---|---|---|---|
| Moro Cojo Floodplain | 650 | 1900 | 800 |
| Tottino Ponds | 550 | 60 | Drill-seeded |
| North Monterey County High School | 400 | 2100 | 3900 |
| Elkhorn Slough Triangle | 85 | 0 | 0 |
| Moon Glow Dairy | 100 | 50 | 30 |
| New Calcagno Site | 40 | 50 | 25 |
| | | | |
| Total | 1825 | 4160 | 4755 |
| | | | |
| **Grand Total** | **10,740** | | |

**Task 6 Education and Outreach**

The focus of our education efforts has been North Monterey County High School, which is located adjacent to one of the restoration sites. We have worked primarily with the science teachers to include the study of watersheds, wetland plants and animals, and water quality, in their curriculum. Student involvement included: 1) growing plants at the school greenhouse; 2) planting native plants at the high school and at the Tottino Ponds site; 3) building barn owl, bat, and swallow boxes; and 4) assisting with bird, invertebrate, and water quality monitoring.

Under our guidance students grew more than 500 plants each year for outplanting. Plants grown at the greenhouse were primarily oaks, ceanothus, lizard tail, silver lupine, and yellow lupine. The cycle of propagating and outplanting the plants that the students grew was repeated each year of the project period. In addition we helped construct and plant a small demonstration garden on the school grounds (Figure 19). This little garden worked very nicely as a demonstration too, inspiring a second teacher to create a second native plant garden at the site. We have begun preparation for that by removing weeds, building a barrier and preparing the soil with mulch.

Figure 19. Greenhouse and native plant demonstration garden at North Monterey County High School.

We took students to restoration sites so they could conduct water quality studies, bird surveys, and surveys of invertebrates. By conducting this follow up students were able to see the value of the restoration of wetlands for improving water quality, and as wildlife habitat. The field trips were focused on the site next to the High School and Tottino Ponds primarily because of accessibility and space for school buses. We also worked with Return of the Natives on greenhouse days and planting days at all of the local schools.

California State University Monterey Bay (CSUMB) classes visited the Moro Cojo floodplain site several times each year to conduct field studies. Courses, where fieldwork at the Moro Cojo site was included in the curriculum, include Basic Chemistry, Introductory Ecology, Quantitative Field Methods, Streamside Restoration, and Advanced Ecology. The chemistry classes conducted water quality sampling analyzing the basic water quality characteristics and then measuring nitrates and phosphate in the lab. The Ecology classes conducted annual surveys of vegetation, birds, and aquatic invertebrates. The Quantitative Field Methods class conducts more advanced individual study of the flora and fauna at the site. This has resulted in some nice multi-year datasets that are on-line at

(http://science.csumb.edu/morocojo/biology/bio_projects.html).

We also worked with several students who conducted their Senior Capstone projects at the restoration sites. These have included studies of aquatic invertebrates, water quality, and vegetation studies. Students from Moss Landing Marine Labs (MLML) continue to work on the Tottino and Catellus sites over the past quarter, as part of their masters research and they have assisted in the refinement of the GIS images of the site and small mammal surveys. In addition, most of the people who worked on the crew that did much of the actual on-the-ground restoration work are biology students from CSUMB or MLML, who were looking to gain some working experience in ecological restoration.

Outreach has been extensive and to a diverse group of people that have included seniors groups, farmers, Monterey County leadership and management, State and Federal agencies, birdwatchers, restoration ecologists, girl scouts, and others. More than 50 tours were given at the restoration sites to groups that ranged in size from 1 to ~ 40 people. On a tour people were introduced to the over arching problems related to water quality, watersheds, and wetlands and then we showed them restoration of these degraded habitats and how that is a solution to most of the water related problems we face. Table 6 includes a list of some of the agencies, organizations, and private entities whose representatives toured the restoration sites.

Table 6. Entities represented by persons that toured the Moro Cojo restoration sites.

| **Agency or Organization** | |
|---|---|
| State Water Resources Control Board | Monterey County Supervisors |
| Monterey County Planning Department | Monterey County Public Works |
| Monterey County Water Resources Control Board | Schaaf & Wheeler Consulting Civil Engineering |
| California Coastal Commission | Central Coast Regional Water Quality Control Board |
| Monterey Country Resource Conservation District | Bureau of Land Management |
| Watershed Institute | Soquel Creek Watershed Group |
| Stanford University | United State Geologic Survey |
| North Monterey County High Student | The Monterey Bay Aquarium |
| California Department of Fish and Game | Girl Scouts of America |
| Santa Cruz County Resource Conservation District | Elkhorn Slough Foundation |

**Task 7 Effectiveness Monitoring**

<u>Water Quality</u>

Between September of 2001 and September of 2003 we created nearly 30 acres of water impoundments at the Moro Cojo floodplain sites (Figure 3 – 10; Table 3), which are either filled seasonally by direct rainfall and runoff from upstream farms (16.2 acres), or that can be filled year-round with runoff augmented with recycled water (13.4 acres). In addition to the 30 acres of ponds, as a result of repairing the perimeter dike, we now can hold water in the perimeter and central ditch system. Although we have not quantified the volume of water that the ditch system contains, it borders the entire east, north, and west edge of the 200-acre parcel, with an average width of ~ 10 feet and a depth of 3-4 feet. In addition to these freshwater impoundments we now retain runoff in numerous small ditches (< 5 feet wide by < 2 feet deep), all of this has resulted in the winter-time flooding of most of the 200-acre parcel with 2-4 inches of water.

The sources of this water include (1) winter runoff from 300 – 400 acres of upstream farmland, (2) direct rainfall on the parcel, (3) non-point source runoff of recycled irrigation water (from irrigation sprinklers), and (4) direct flow of recycled water (from the irrigation pond). In the past, virtually all of the runoff water drained from the site through a breach in the main dike, allowing it to flow into the main channel of Moro Cojo Slough (Figure 2). These changes alone have led to improvements of water quality in Moro Cojo Slough by reducing sediment, nutrient, and biocide inputs, from 300 – 400 acres of agricultural lands and 200 acres of former agricultural/rangeland, from reaching the slough. The real impact of this project on water quality in Moro Cojo Slough, is in that the success of this project has led to new opportunities to implement the next phase of the Moro Cojo Slough Management and Enhancement Plan, which will bring the same sorts of changes that been implemented at the Moro Cojo floodplain site to the entire middle and lower Moro Cojo watershed and the lower Castroville watershed.

At this time improvements to water quality in the Moro Cojo Slough as a whole are not measurable, however water quality improvements at the restoration site are. The ponds are linked in groups allowing water to flow onto the property from direct runoff or from the ditch system and then into each successive pond. Vegetation in the ponds varies considerable from relatively dense herbaceous perennial vegetation or annual grasses to large areas of open water (Figure 20). Water flows from the irrigation reservoir into Pond C, then to ponds E & F, and then into the Central Ditch, which has an upper and lower component. Water also flows from the irrigation reservoir into Ponds C & D and then Pond H. Following significant rainfall events (> 2 inches) this water is joined by runoff flowing into Pond H (from offsite) and then most of this water flows into Pond G (Figures 10 & 11).

To evaluate water quality conditions as water flowed between sources and destinations we collected and analyzed 109 water samples over a 3-month period in 2003. Field data collected included temperature (°C), dissolved oxygen (mg/l), salinity (ppt), and pH. Laboratory analysis of nitrates ($N0_3$-N), and total ammonia ($NH_3$-N), and turbidity were conducted at the Central Coast Watershed Studies laboratory at CSUMB under the supervision of Dr. Fred Watson. Water sampling was limited in time due to stochastic supply of recycled water and limited rainfall during 2002. Ponds for which data is missing from later in the season, had dried up.

Water quality samples were collected and analyzed under the guidelines of the QAPP. Water quality conditions were measured in the field with a YSI Environmental 556 MPS multiprobe, with built in barometer. In the field turbidity analysis was done with a HACH 2100P Turbidimeter. Field data was recorded on standard data sheets, which are included in Appendix D. Laboratory analysis of nitrate, total ammonia, and turbidity were performed by the Central Coast Watershed Studies group at California State University Monterey Bay. Water quality data collected in the field and the complete results of the laboratory analysis are also included in Appendix D.

Pond C

Pond F

Figure 20. Impoundments at the Moro Cojo floodplain site contain both heavily vegetated (Pond C) and open-water (Pond F) components.

Water quality conditions varied widely at different sampling locations at the Moro Cojo floodplain site (Table 7). Although we do not currently have sufficient data to conclusively identify the sources of variability, we can draw some conclusions about how physical or biological factors may be improving or decreasing water quality. For example, the ponds and ditches vary in water depth and amount and types of vegetation, which can affect dissolved oxygen and temperature. There are low lying areas in the ditch system where water collects and eventually evaporates for percolates, likely left behind elevated concentrations of dissolved constituents such as salt, which can also negatively affect dissolved oxygen concentrations. Water flowing through these ditches can be very saline, and have very low or very high pH levels. This suggests high concentrations of salts in the soil as runoff after storm events can return these same locations to freshwater conditions with more balanced pH.

Table 7. Ranges of water quality conditions measured at the Moro Cojo floodplain site.

| **Parameter** | | **Range** | **Location** | **Date** |
|---|---|---|---|---|
| Temp (°C) | Low | 13.13 | Pond F | 16-Mar |
| | High | 25.66 | Pond G | 15-Mar |
| Dissolved Oxygen | Low | 1.05 | Pond C | 15-Mar |
| (mg/l) | High | 23.85 | CDL | 14-Mar |
| Salinity (ppt) | Low | 0.14 | Pond F | 17-Apr |
| | High | 38.94 | CDL | 12-Apr |
| PH | Low | 6.14 | Pond C | 16-Mar |
| | High | 12.4 | Pond B | 17-Mar |
| Turbidity (NTU) | Low | 6.1 | CDL | 25-Feb |
| | High | 592.0 | Pond C | 12-Apr |
| Nitrate | Low | 0.0 | Pond B,E,F,G,J&Res | 5-Mar |
| (mg/l $NO_3$-N) | High | 9.3 | CDU | 7-May |
| Total Ammonia | Low | 0.0 | Pond I, CDU, CDL | 30-Apr |
| (mg/l $NO_3$-N) | High | 6.2 | Pond C | |
| | | | | |

Note: CDU – Central Ditch Upper; CDL- Central Ditch Lower; Res- Irrigation Reservoir.

Nitrate loads in the impoundments were relatively low when compared to regional data (Anderson et al. 2003). This is most likely due to low nitrate levels in the processed recycled water and the fact that runoff was accumulated from only 300-400 acres of agricultural lands. On the other hand, total ammonia reached levels that were considerably higher than most sites sampled in the region.

The importance of these elevated nitrogen concentrations depend upon the perspective. In terms of drinking water standards, which are 10 mg/l for Nitrate and 30 mg/l for total ammonia, none of the concentrations we observed are significant in that they do not exceed these standards. On the other hand concentrations we measured far exceeded background historical concentrations as well as thresholds for freshwater ecosystem health. Anderson et al 2003, reviewed relative regional and national data on background levels, toxicity levels for fish, amphibians, and invertebrates and established standards for comparison in their study that addressed critical ecological standards. The standard they established for nitrate is 1.2 mg/l $NO_3$-N and for total ammonia they established

0.025 mg/l $NO_3$-N as their threshold. Their study included analysis of several thousand water samples from a number of Monterey Bay watersheds, and it is the most thorough and current source of comparative data regarding water quality conditions within the Moro Cojo and Castroville watersheds. We have used these same threshold levels in analysis and discussion of nitrate and total ammonia data we collected.

Of the 90 samples we analyzed for nitrate concentrations 7 samples, or 8%, exceeded standards used by Anderson et al (2003). Of the 91 samples we analyzed for total ammonia 63, or 69%, exceed these standards (Figure 21). The highest single nitrate concentration we measured was 9.3 mg/L from the upper portion of the Central Ditch. The next highest concentrations were both in samples from Pond D (3.9 and 2.9 mg/L).

The highest concentration of total ammonia was from Pond C (6.2 mg/L). This pond is hydraulically linked to the adjacent irrigation reservoir, which also showed relatively high levels of total ammonia (Figure 21). Ammonia is also present at relatively high levels in Pond D, which is hydraulically linked to Pond C. Most of the remaining ponds have relatively low levels of total ammonia, though most are above the standards used by Anderson et al (2003). Exceptions are Ponds A and B, and Pond J, which had elevated levels.

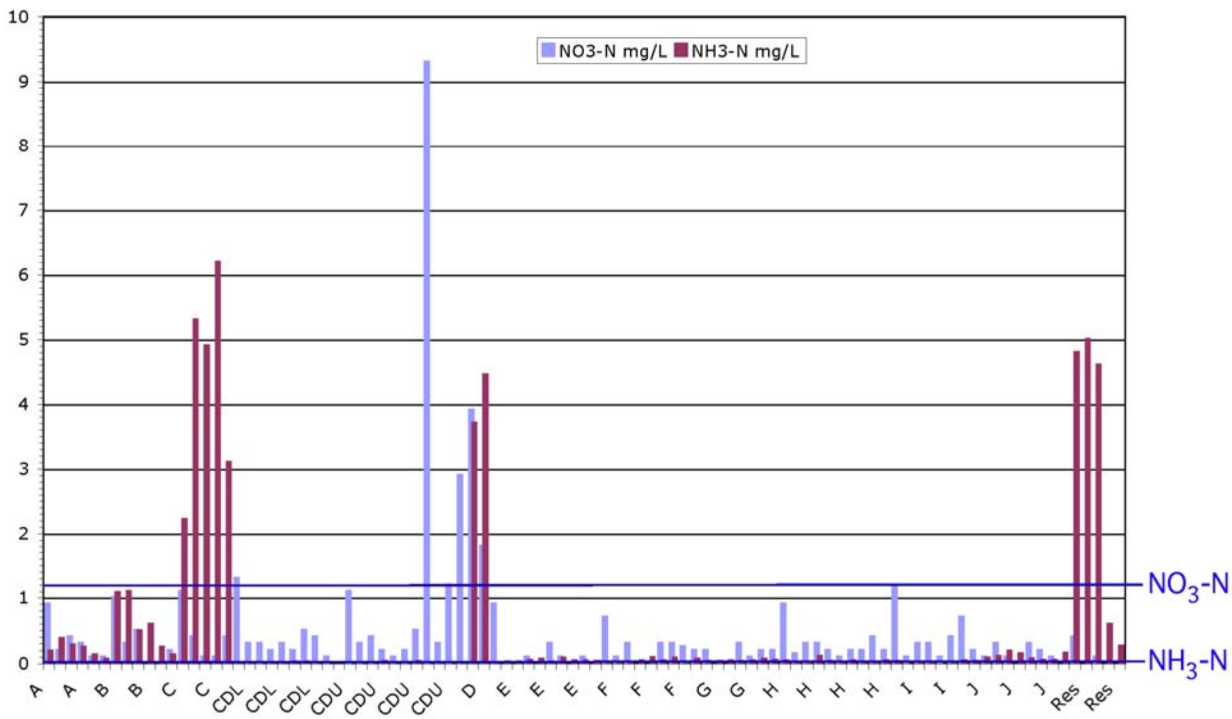



Figure 21. Nitrate and total ammonia concentrations in ponds at the Moro Cojo floodplain restoration site, and comparative threshold levels in blue (N= 90 for $NO_3$-N; 91 for $NH_3$-N).

Ponds A and B are directly downstream from a swale and drainage that directs irrigation water from the adjacent farm to runoff onto the Moro Cojo floodplain site, where it tended to pond even before we enhanced the impoundments. Many years of runoff may have resulted in a build up of nitrogen in the soil. The same could explain the elevated levels of total ammonia in Pond D. The soils at what is now Pond J, on the other hand, may not have ever received substantial inputs of runoff, suggesting the elevated ammonia concentrations represent chemical conversion of nitrogen compounds that are either in the recycled water itself or are picked up as the water flows over the farm soils. This suggest the elevated levels of ammonia are directly associated with the water and runoff and not an interaction with nitrogen deposited in the soils of the Moro Cojo floodplain site.

Although we did measure nitrate levels that exceeded the reference standards (Anderson et al 2003), and in some cases these exceeded the standards by large margins, the number of samples where concentrations were excessive is relatively small. Nonetheless, looking at the over all results and considering these within the context of how and where water flows between the ponds, there may be evidence of soil/water interactions in the transport and deposition of nitrogen.

In the impoundments, recycled water flows from the irrigation reservoir (Res) to Pond C, to Pond E & F, then into the Upper and Lower portions of the Central Ditch, respectively. Recycled water also flows along another path – from the reservoir to Pond C, through Pond D (which is basically a large wet area), to Pond H (where it is joined by water in the perimeter ditch that has flowed there from upstream locations). During the rainy winter months the perimeter ditch and Pond H fill and overflow into the large impoundment, Pond G.

We analyzed the monthly mean nitrates and total ammonia concentrations to understand changes in water chemistry as water flowed from pond to pond along these two hydraulic pathways (Table 8). Figures 22, 23, and 24 present mean nitrate and mean total ammonia concentrations for February, March, and April respectively, in water sampled between the reservoir and the Central ditch. We do not have data for the reservoir for February, but we do have data for March and April. The mean nitrate value April was < 0.00, but had a range of 0.0 – 0.4 $NO_3$-N mg/L.

Table 8. Mean nitrate ($NO_3$-N mg/L) and total ammonia ($NH_3$-N mg/L) in the ponds, by month.

| **Location** | **Mean $NO_3$-N mg/L** | | | **Mean $NH_3$-N mg/L** | | |
|---|---|---|---|---|---|---|
| | Feb | Mar | Apr | Feb | Mar | Apr |
| Reservoir | N/D | 0.17 | 0.00 | 2.22 | 4.80 | 0.43 |
| Pond C | 1.10 | 0.20 | 0.40 | 0.01 | 5.47 | 3.10 |
| Pond E | 0.90 | 0.10 | 0.10 | 0.02 | 0.04 | 0.05 |
| Pond F | 0.70 | 0.18 | 0.24 | N/D | 0.04 | 0.05 |
| Central Ditch - Upper | 1.10 | 0.24 | 2.83 | 0.01 | 0.01 | 0.02 |
| Central Ditch - Lower | 1.30 | 0.26 | 0.33 | N/D | 0.01 | 0.02 |

Differences in nitrate concentrations were not significant between months (single-factor ANOVA, $P > 0.15$) or between ponds (single-factor ANOVA, $P > 0.45$). The same is true for total ammonia, differences were not significant between months (single-factor ANOVA, $P > 0.52$) or between ponds (single-factor ANOVA, $P > 0.9$).

Nonetheless, evaluating the monthly average concentrations of nitrate and total ammonia do reveal some important patterns. There are very high concentrations of total ammonia in both the irrigation reservoir and in Pond C, which are not evident in any of the downstream locations. Monthly averages of nitrate concentrations in the ponds tend to reflect concentrations in the reservoir in February and March (Figure 22 & 23), however elevated levels in the Central Ditch, suggest additional sources of nitrate concentrations, such as the soil in the ditch.

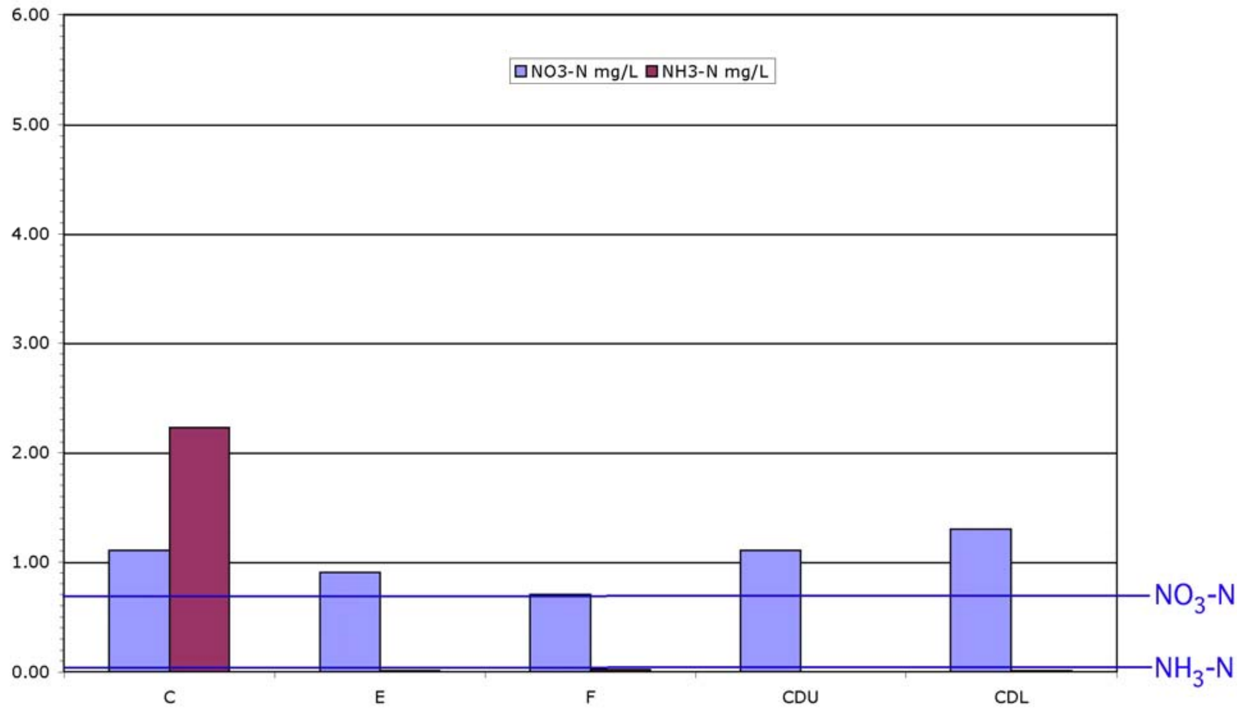



Figure 22. February mean nitrate ($NO_3$-N mg/L) and mean total ammonia ($NH_3$-N mg/L) concentrations as water flowed from Pond C through the series of ponds to lower Central Ditch, and comparative threshold levels in blue (N = 11).

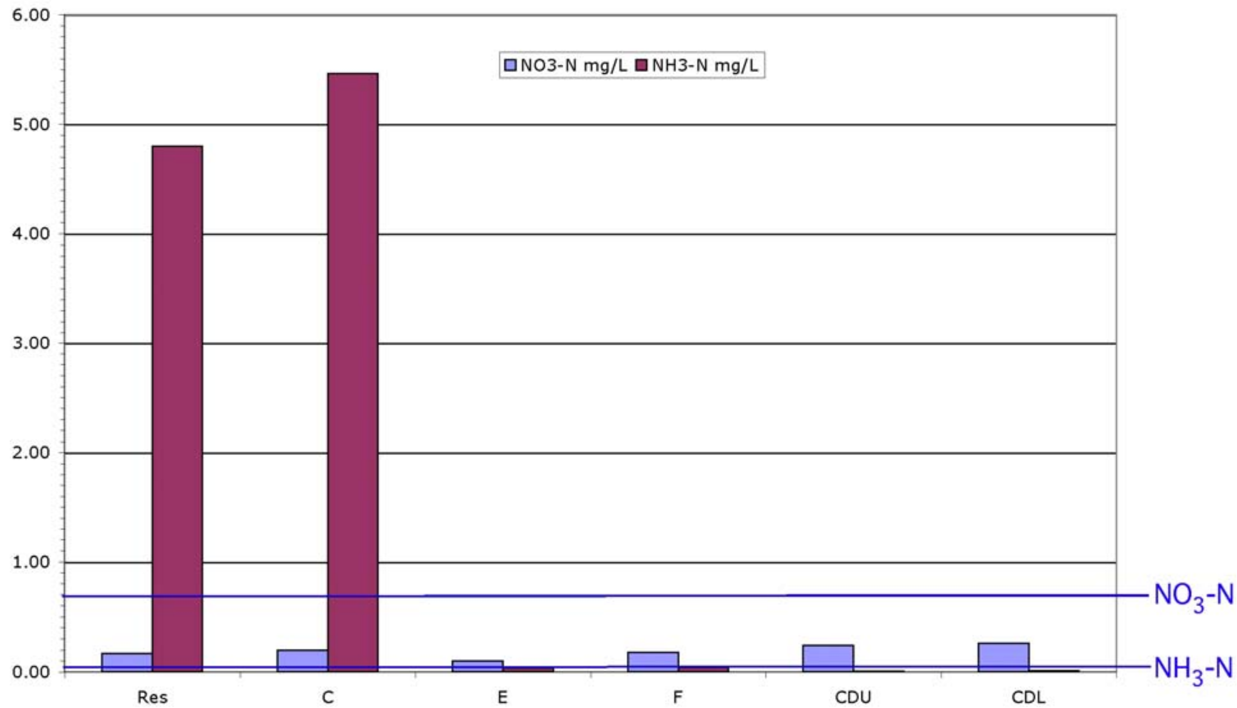



Figure 23. March mean nitrate ($NO_3$-N mg/L) and mean total ammonia ($NH_3$-N mg/L) concentrations as water flowed from Pond C through the series of ponds to lower Central Ditch, and comparative threshold levels in blue (N = 59).

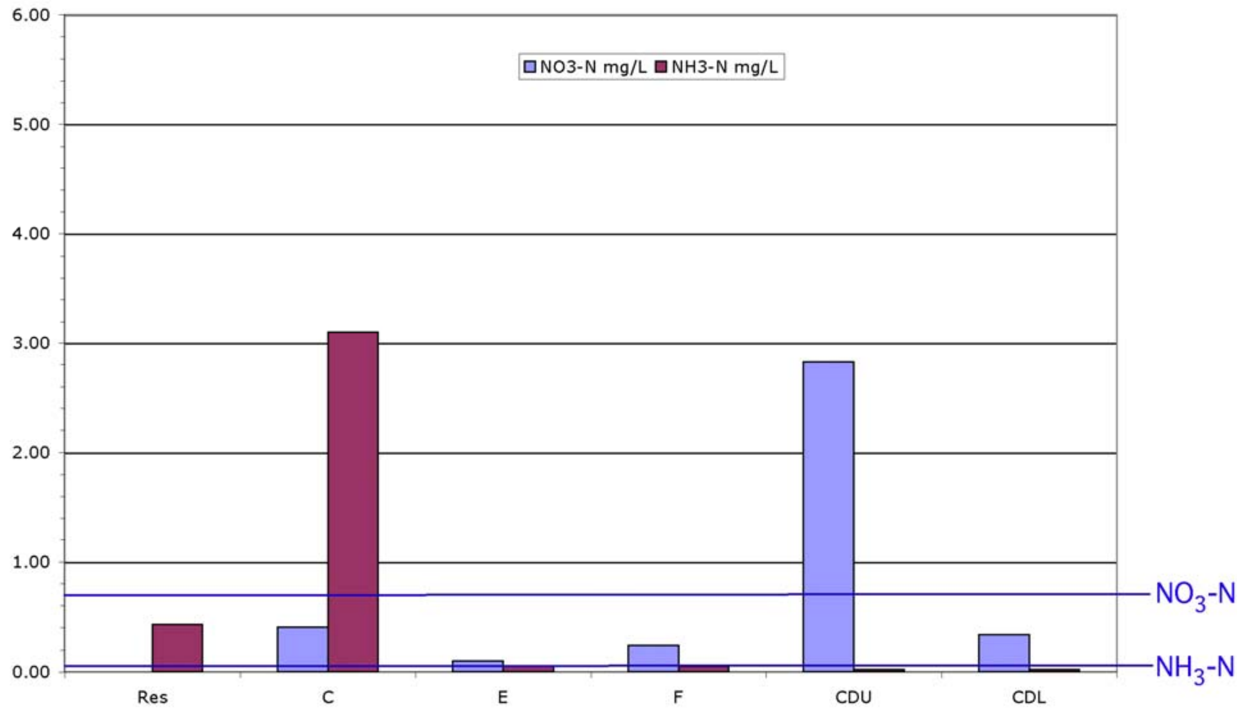



Figure 24. April mean nitrate ($NO_3$-N mg/L) and mean total ammonia ($NH_3$-N mg/L) concentrations as water flowed from Pond C through the series of ponds to lower Central Ditch, and comparative threshold levels in blue (N = 27).

The Monterey Regional Water Pollution Control Agency (MRWPCA) monitors chemical constituent concentrations in the recycled water at the processing facility on a regular basis, and these data are readily available (MRWPCA 2003). Nitrate ($NO_3$-N) concentrations as reported by the agency as parts per million (ppm). The average nitrate concentrations they report of the month of March 2003, when converted to mg/L, is less than 0.0005 $NO_3$-N mg/L. In fact the highest concentration they report for the entire year is 0.002 $NO_3$-N mg/L. Clearly, significant concentrations of nitrate are not being delivered to the reservoir from the recycled water processing facility.

Nitrate sources are most likely runoff from the farm directly onto the Moro Cojo floodplain site and/or runoff from the fields into the reservoir (during the winter months there is direct runoff into the pond, but probably important is that runoff is collected at other sites on the farm and piped into the main reservoir). This is supported by the elevated levels of nitrate observed in February, at the end of the rainy season, and then subsequent tapering off of concentrations in March and April, when there is little rain/runoff. The one important divergence from this pattern is the high concentration of nitrate in the upper portion of the central ditch observed in April (Figure 24). In fact nitrate reached a concentration of 9.3 mg/L at one point. One possible explanation is that nitrate has been concentrated at that location in the past. That particular location is one of the main ditches that receives runoff from the farm and the site itself, and has done so for several decades at the least. Nonetheless, subsequent measurements of nitrate concentrations at that locale and at the downstream site (CDL) suggest high levels are not sustained and are at least diluted as the nitrate moves downstream.

The high concentrations of total ammonia in the reservoir and at Pond C are of concern in that they exceed concentrations measured at all but a few locations that have been studied, throughout several Monterey Bay watersheds (Anderson et al 2003). On the other hand the data strongly indicate that high total ammonia concentrations are not being transported downstream, thus there must be some conversion or loss from the system occurring in the reservoir and Pond C.

The source of the ammonia is at this point uncertain, however it is most likely a breakdown product of manure used as a fertilizer on the farm (i.e – urea ($NH_2$) to ammonia ($NH_3$) and ammonium ion ($NH_4$). The most plausible hypothesis, at this point, to explain the loss of ammonia from the reservoir and Pond C is that ammonia is coming out of solution and de-gassing as the water in the ponds heat up.

Substantiating this will require further study, which will be carried out in conjunction with Phase II Implementation of the Moro Cojo Management and Restoration Plan.

Bird Monitoring

We conducted bird surveys at both the Tottino Ponds site and at the Moro Cojo floodplain site. At the Tottino Ponds site we continued to use a protocol established during earlier restoration work at this site. The observer drives to each pond and begins surveying from their vehicle. After all birds that are seen from the vehicle are counted, the observer steps out of the vehicle to complete the count. We identify and count all birds observed at each pond. Birds that fly over the site without stopping are noted as “fly-overs”. Surveys are completed within an hour and were conducted at least once a month for the project period. Each plot is surveyed for a period of 10 minutes. Plots were established in April 2001 and initial surveys conducted in May of that year.

The expanse of the Moro Cojo floodplain site required we use a different sampling strategy. We established 5 variable circular plots for surveying birds on a monthly basis. An additional plot was added in December of 2002, in order to increase the resolution of the surveys. Variable circular plots allow for comparison of avian survey results from multiple habitat types with widely varied plot sizes, and provide an index of species’ relative abundance and avian community structure. Surveys were conducted from the plot’s centers. All birds observed were identified to species, and the number of individuals, and their activity and habitat associations were recorded. During the project period 24,083 birds representing 108 species were counted during monthly surveys at the Moro Cojo Site (Table 9).

Table 9. Avian species observed at the Moro Cojo restoration site during variable-circular plots, May 2001-September 2003.

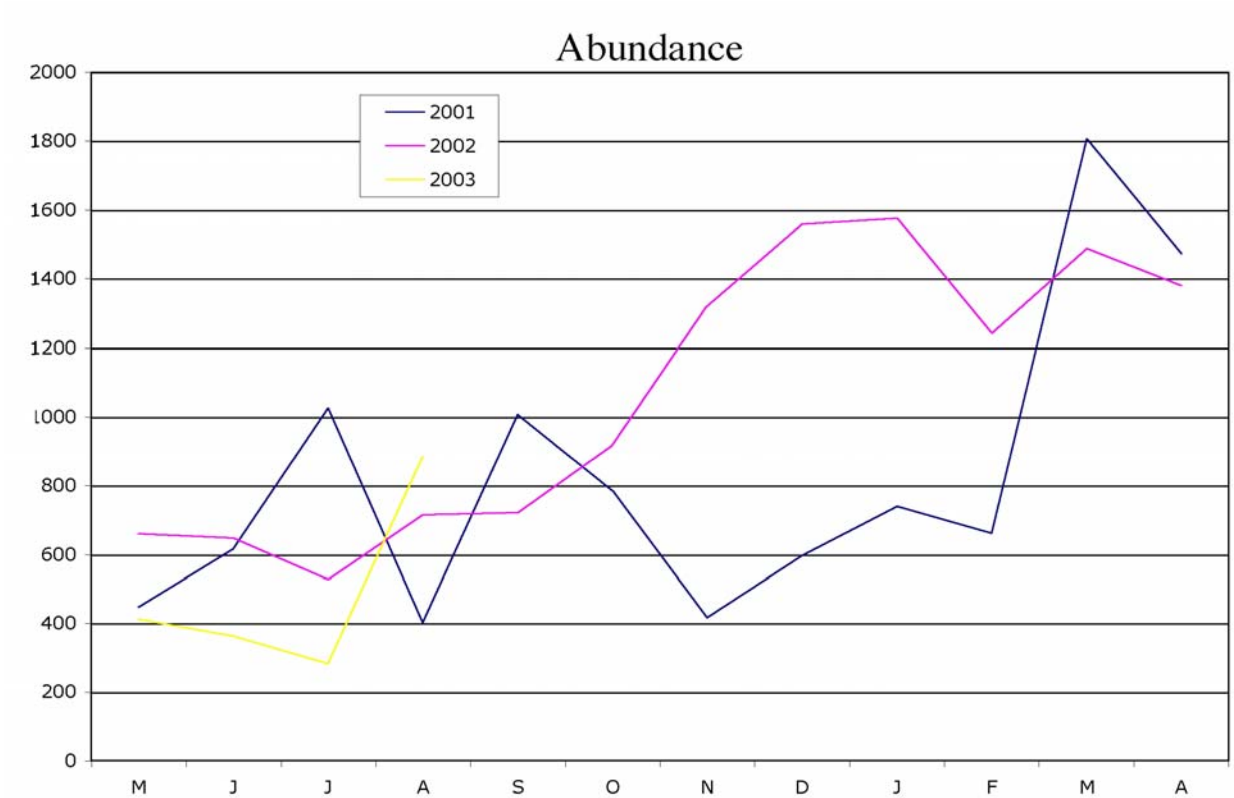
| | | | |
|---|---|---|---|
| American Advocet | Cliff Swallow | Loggerhead Shrike | Say's Phoebe |
| American Bittern | Common Goldeneye | Long-billed Curlew | Semipalmated Plover |
| American Coot | Common Raven | Long-billed Dowitcher | Short-billed Dowitcher |
| American Crow | Common Yellowthroat | Mallard Duck | Short-eared owl |
| American Goldfinch | Copper's Hawk | Marbled Godwit | Snow Goose |
| American Kestrel | Double-crested Cormorant | Marsh Wren | Snowy Egret |
| American Pipit | Dunlin | Merlin | Song Sparrow |
| American Wigeon | Eared Grebe | Mourning Dove | Sora |
| Baird's Sandpiper | European Starling | Northern Harrier | Tree Swallow |
| Bank Swallow | Gadwall | Northern Pintail | Tundra Swan |
| Barn Owl | Golden Eagle | Northern Rough-winged Swallow | Turkey Vulture |
| Barn Swallow | Great Blue Heron | Northern Shoveler | Virginia Rail |
| Belted Kingfisher | Great Egret | Osprey | Wellow Warbler |
| Black Phoebe | Greater Scaup | Pectoral Sandpiper | Western Grebe |
| Black-bellied Plover | Greater White-fronted Goose | Peregrine Falcon | Western Gull |
| Black-crowned Night-Heron | Greater Yellowlegs | Pied-billed Grebe | Western Kingbird |
| Black-necked Stilt | Green-winged Teal | Red Shouldered Hawk | Western Meadowlark |
| Bonaparte's Gull | Horned Lark | Red-winged Blackbird | Western Sandpiper |
| Brewer's Blackbird | House Finch | Redneck Phalarope | Whimbrel |
| Brown-headed Cowbird | Killdeer | Redtail Hawk | White-crowned Sparrow |
| Bufflehead | Lapland Longspur | Ringed-billed Gull | White-faced Ibis |
| California Gull | Lawrence's Goldfinch | Ross's Goose | White-tailed Kite |
| Canada Goose | Least Sandpiper | Ruby-crowned Kinglet | Willet |
| Canada Goose - "Cackling" race | Lesser Scaup | Ruddy Duck | Wilson's Snipe |
| Caspian Tern | Lesser Yellowlegs | Ruddy Turnstone | Wilson's Warbler |
| Cinnamon Teal | Lincoln's Sparrow | Savannah Sparrow | Yellow-rumped Warbler |

We started avian surveys at the Moro Cojo floodplain site the year before any major restoration implementation began at that site. This gave us a baseline to compare the affect of restoration on the avian community at the site. A baseline, which included annual variability in species abundance and diversity, such as periods when birds visit the site while on migration through the region (Table 10).

Table 10. Total and per-plot abundance and species diversity observed during variable circular plot surveys for birds, conducted at the Moro Cojo floodplain restoration site 2001-2003.

| Month | Year | Total Abundance | Diversity | Number of | Mean Abundance | Stand. | Mean Diversity | Stand. |
|---|---|---|---|---|---|---|---|---|
| | | (All Plots) | (All Plots) | Plots | per Plot | Dev. | per Plot | Dev. |
| 5 | 2001 | 447 | 35 | 5 | 89.4 | 38.51 | 14.4 | 4.22 |
| 6 | 2001 | 617 | 30 | 5 | 123.4 | 51.67 | 14.2 | 4.55 |
| 7 | 2001 | 1026 | 35 | 5 | 205.2 | 98.12 | 17.6 | 5.41 |
| 8 | 2001 | 402 | 40 | 5 | 80.4 | 28.45 | 15 | 7.75 |
| 9 | 2001 | 1006 | 44 | 5 | 201.2 | 46.06 | 19 | 4.9 |
| 10 | 2001 | 785 | 37 | 5 | 157 | 46.33 | 18.8 | 3.19 |
| 11 | 2001 | 417 | 30 | 5 | 83.4 | 43.7 | 14.4 | 4.22 |
| 12 | 2001 | 596 | 37 | 5 | 119.2 | 93.22 | 10.8 | 5.63 |
| 1 | 2002 | 739 | 41 | 5 | 147.8 | 159.24 | 14.6 | 8.38 |
| 2 | 2002 | 661 | 29 | 5 | 132.2 | 157.81 | 11.2 | 6.38 |
| 3 | 2002 | 1806 | 52 | 5 | 361.2 | 335.41 | 19.8 | 9.12 |
| 4 | 2002 | 1472 | 47 | 5 | 294.4 | 205.39 | 19.8 | 9.42 |
| 5 | 2002 | 660 | 28 | 5 | 132 | 73.78 | 14.2 | 2.59 |
| 6 | 2002 | 647 | 36 | 5 | 129.4 | 66.84 | 15.8 | 6.91 |
| 7 | 2002 | 527 | 33 | 5 | 105.4 | 82.65 | 14.8 | 3.11 |
| 8 | 2002 | 715 | 43 | 5 | 143 | 114.37 | 15.8 | 5.22 |
| 9 | 2002 | 721 | 50 | 5 | 144.2 | 95.41 | 19.8 | 5.07 |
| 10 | 2002 | 918 | 36 | 5 | 183.6 | 155.44 | 17.6 | 7.23 |
| 11 | 2002 | 1321 | 41 | 5 | 264.2 | 357 | 20.6 | 7.13 |
| 12 | 2002 | 1558 | 58 | 6 | 259.67 | 267.28 | 21.83 | 14.08 |
| 1 | 2003 | 1575 | 58 | 6 | 262.5 | 281.73 | 20.33 | 16.92 |
| 2 | 2003 | 1242 | 56 | 6 | 207 | 171.1 | 20.17 | 10.32 |
| 3 | 2003 | 1488 | 53 | 6 | 248 | 186.5 | 19.83 | 9.75 |
| 4 | 2003 | 1381 | 57 | 6 | 230.17 | 172.79 | 19.17 | 9.66 |
| 6 | 2003 | 413 | 30 | 6 | 68.83 | 53.59 | 10.33 | 5.47 |
| 7 | 2003 | 364 | 28 | 6 | 60.67 | 53.05 | 9.67 | 5.61 |
| 9 | 2003 | 282 | 33 | 6 | 47 | 43.22 | 12 | 8.39 |
| 10 | 2003 | 885 | 45 | 6 | 147.5 | 147.88 | 18.17 | 11.55 |

Surveys conducted after the formation of the ponds on the Moro Cojo floodplain site revealed the highest species diversity and abundances, observed at that site to date, during the wet winter and spring months when the ponds were full. Both abundance (Figure 25) and species diversity were clearly affected by the presence of water. Abundance and species diversity during year 1 (2001) remained relatively low from May of 2001to January 2001, then increased dramatically in February of 2002. The increase in both abundance and species diversity coincide with the development of the first ponds, which filled with runoff and then were maintained for a period of months with recycled water.



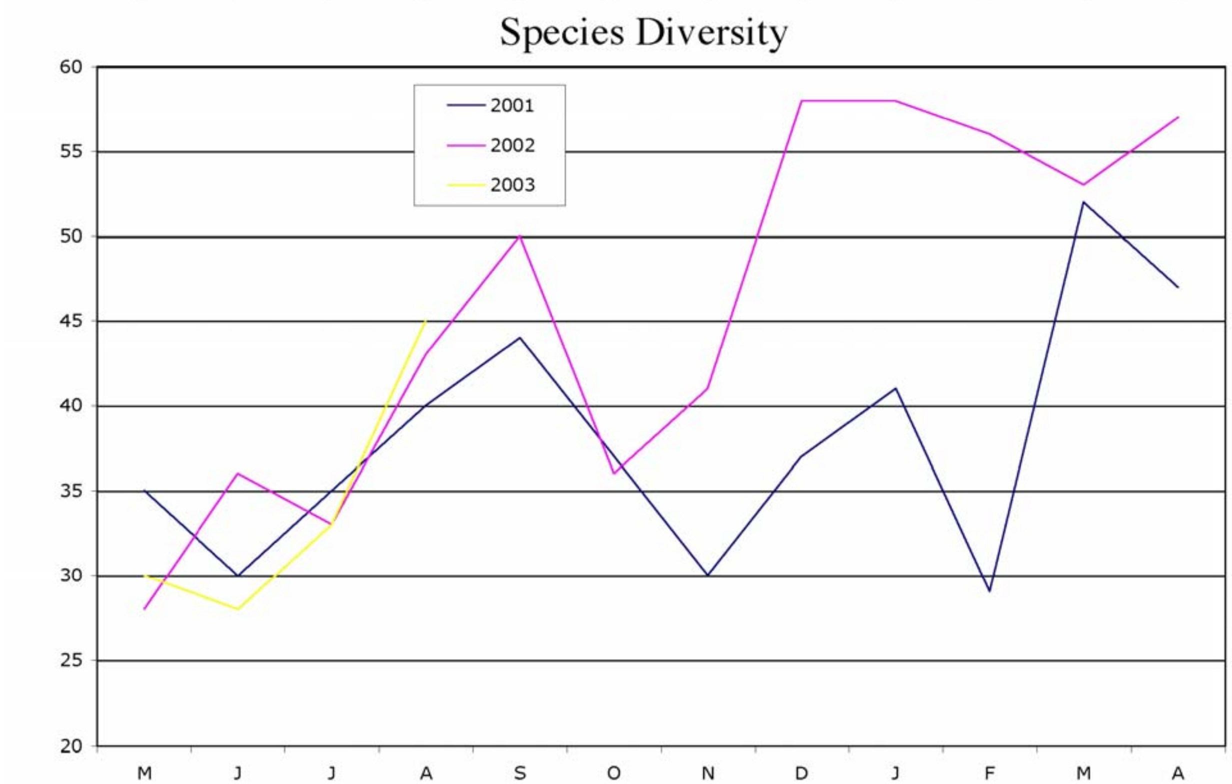




Figure 25. Avian abundance and species diversity observed during variable circular plot surveys conducted at the Moro Cojo floodplain restoration site 2001-2003.

The number of birds and the diversity of species declined during the dry months of 2002 (May through September), and then again increased in October. Again coincident with our filling the ponds with recycled water, an activity which at the time was limited by the schedule of the farming operations. During the dry summer months the adjacent farm lays fallow and the agricultural reservoir water level remains low, so that no water can flow to the ponds, which eventually dry up. In October they began to prepare the field for planting and refilled the reservoir, allowing us to refill the ponds, and we again observed an increase in both abundance and species diversity.

This pattern is even more evident when abundance and species diversity observed at the individual plots is analyzed. Plots 1 and 5 account for the majority of birds observed during the wet season (Figure 26), with fairly dramatic increase in both abundance and diversity. Plots 1 and 5 are located along the farm edge (near Ponds C – F, I & J) and show dramatic increases in both abundance and species diversity during the wet season and when the ponds are filled with recycled water. Plots 2 – 4 are in areas located out in the field further away from the ponds, and avian abundance and diversity remained relatively constant during the study period.

While the numbers of birds and species is in important, but so is the makeup of avian community. The ponds attracted species such as white-faced ibis, never before recorded at this site. Species such as the ibis are now quite rare to this region most likely due to the loss of freshwater wetlands like the ones we've created during the course of this project.

Furthermore, the fact that 6 White-Faced Ibis remained in the ponds at the Moro Cojo floodplain site for more than a month is an important indicator of the function of the created ponds. Clearly, the ponds are functioning to provide forage opportunities and sufficient cover that these birds were able to remain, undisturbed, for an extended period of time. Similarly, the fact that Soras and Virginia Rail are now resident in the ponds is further evidence that these are beginning to function as wetland ecosystems. On the other hand, the fact that these relatively immature pond communities attract these rare species is probably an important indicator of just how rare freshwater wetland habitats are throughout this region.

We built and installed 2 Barn Owl nest boxes at the Moro Cojo floodplain site, hoping to encourage these native birds renowned for their prodigious consumption of rodents. Both owl boxes have been occupied and broods were successfully produced at both nest boxes in 2003. A third owl box was installed at the new Calcagno site as well. A local Girl Scout group built 30 swallow boxes, which we installed at the Moro Cojo Floodplain site. All of these were immediately occupied and used for nesting.

At the Tottino Ponds site we have observed 106 species of birds. Although the data collected on birds Tottino Ponds is collected in a more subjective basis, basically focused on keeping track of the species that are present, the species present considerable diversity, particularly when compared to what species would have been present when the site was a disced field.

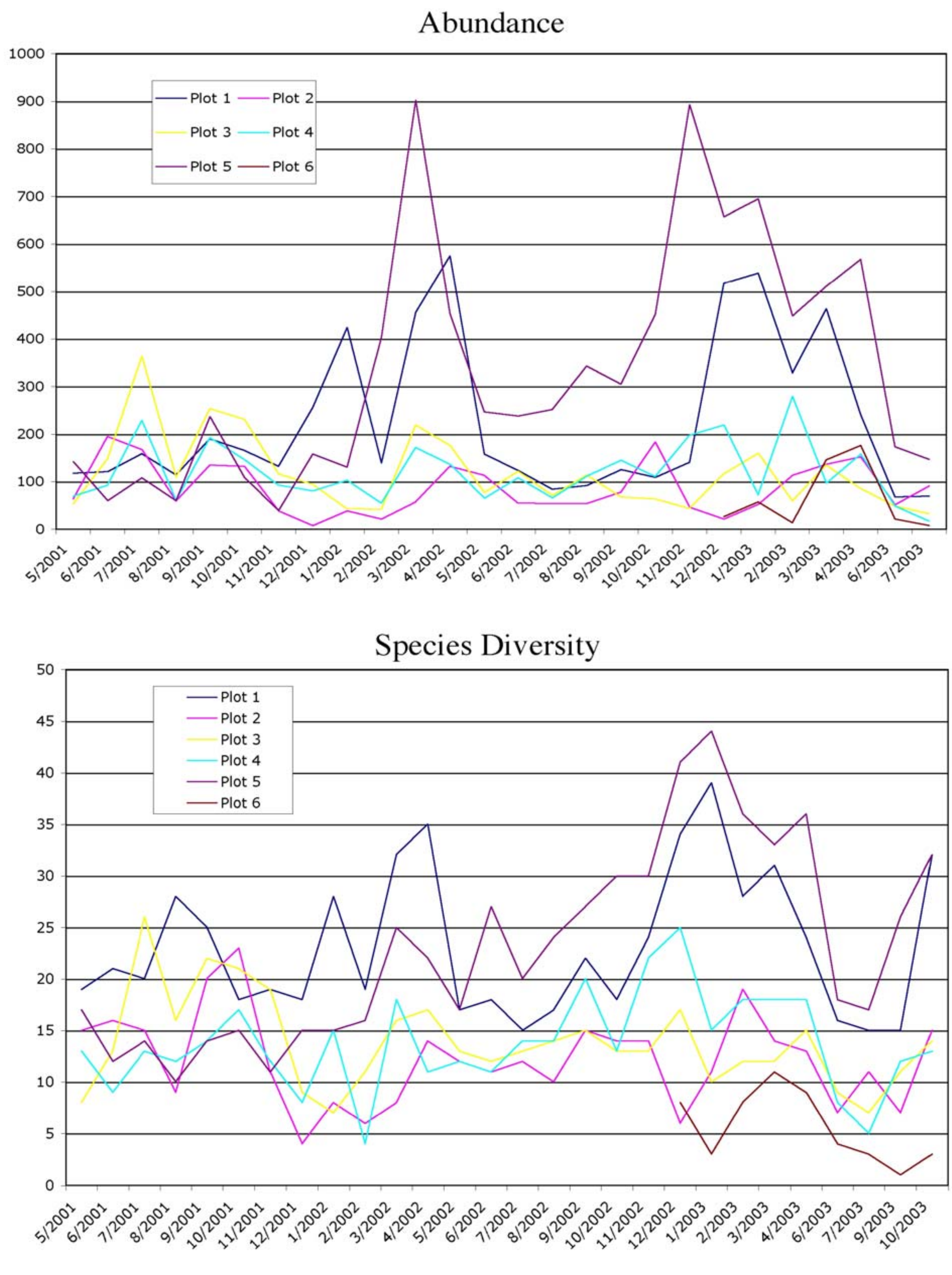



Figure 26. Avian abundance and species diversity observed during variable circular plot surveys conducted at the Moro Cojo floodplain restoration site 2001-2003.

Small Mammal Monitoring

We surveyed small mammals at the Tottino Ponds and Moro Cojo floodplain restoration sites to identify species diversity, relative abundance, and the use of different habitats found around the farms and the restoration sites. This work was initiated after Sunset Farms expressed concern that crop damage, by rodents, had increased dramatically after cattle were removed from the Moro Cojo floodplain site. They suggested that in the past the cattle removed most of the plant biomass, thereby depriving rodent populations of both food and cover. They also suggested that since the cattle had been removed, the vegetation recovered, and so did rodent populations, which since the site had long been heavily grazed, had few natural predators. In response, we began small mammal surveys to identify where rodent populations occurred, species diversity, and relative abundance (using live traps; see Appendix B - California Department of Fish and Game Collection Permit).

Traps were typically set in either a grid or in straight lines along pond or farm edges. Each location was trapped for 3-4 consecutive nights, with traps being checked each morning. Captures were identified to species and released. Dominant plant communities that traps were placed in were identified and recorded.

We surveyed rodents in three native and four non-native habitat types, and around the ponds. Native plant communities that we surveyed for small mammals were pickle weed, creeping wild rye, and a diverse native plant community. Non-native habitats surveyed included Mediterranean rye, Mediterranean barley, thistle community, and mixed non-native grass community. The ponds were occupied by a mix of native and non-native plants
(Table 11).

Table 11. Vegetation composition at surveyed habitats at the Moro Cojo floodplain restoration site.

| Habitat | Habitat Description |
|---|---|
| Pickle weed | Pickle weed - 99%,Frankenia, Lolium spp., Mediterranean barley on edges, some places bare (0-50%, on average 15%) |
| Creeping wild rye | Dense cover of creeping wild rye - 70%; dispersed patches of saltgrass and rush, scattered bushes of salt brush |
| Diverse native community | Stable native community composed of salt brush, saltgrass, Frankenia and pickle weed, scattered patches of rabbit-root grass |
| Ponds | Restored ponds with a matrix of native emergent species including bulrush, California tule, pale spike rush, mixed with non-native brass buttons, and rabbit-foot grass. |
| Lolium | Dense uniform cover of Italian rye - 90% |
| Mediterranean barley | Non-native meadow composed of Mediterranean barley - 80%, with patches of Lolium spp. and rabbit-foot grass |
| Thistle community | Non-native forb community of common sow thistle, yellow star thistle, rabbit-foot grass, Lolium spp. (1:1:1:1); scattered patches of Frankenia, curly dock |
| Mixed non-native grass community | Uniform cover of Lolium spp. and Perennial barley (1:1) |

We set a total of 460 traps, over a trapping period of 18 nights. We trapped a total of 137 animals representing 4 rodent species. These include native California vole (*Microtus californicus*), deer mouse (*Peromyscus maniclatus*), harvest mouse (*Reithrodontomys megalotis*), and the non-native house mouse (*Mus musculus*). In the surveyed habitats we observed a range from a single species to all four species with a diversity index (Shannon-Weiner Function) ranging from 0 to 1.04 (Table 12).

Table 12. Results of small mammal trapping in various habitat types.

| Habitat | # Traps | # Trappings | # Species | Relative Abundance (#trappings / #trapnights) | Species Diversity (Shannon-Wiener Function) |
|---|---|---|---|---|---|
| Pickle Weed | 41 | 12 | 2 | 7.32 | 0.29 |
| Lolium | 41 | 23 | 2 | 14.02 | 0.18 |
| Thistle Community | 18 | 5 | 1 | 6.94 | 0.00 |
| Creeping Wild Rye | 51 | 18 | 2 | 11.76 | 0.45 |
| Non-native grass community | 39 | 18 | 1 | 15.38 | 0.00 |
| Mixed native plant community | 30 | 6 | 3 | 6.67 | 1.04 |
| Mediterranean Barley | 60 | 12 | 3 | 6.67 | 0.62 |
| Ponds (before flooding) | 90 | 25 | 4 | 6.94 | 0.66 |
| Ponds (after flooding) | 90 | 18 | 2 | 5.00 | 0.35 |
| Total | 460 | 137 | 4 species | N/A | N/A |

We found important differences in the use of different habitats by small mammals. Non-native grasses supported the highest relative abundances of all habitats surveyed, and this held true for both stands of Italian rye (Lolium) and for mixed stands of Italian rye and barley (Figure 25). Pickleweed, mixed native communities, and the ponds had the lowest relative abundances. We found higher relative abundance in a large stand of native creeping wild-rye but that may reflect the fact that we had mowed down all of the non-native grasses that surrounded this stand, leaving no other habitat. This conclusion is supported by small mammal survey data from a coastal dune site we had restored previously. At that location a large patch of creeping wild rye surrounded by a diverse community of native dune vegetation, revealed very low numbers of small mammals.

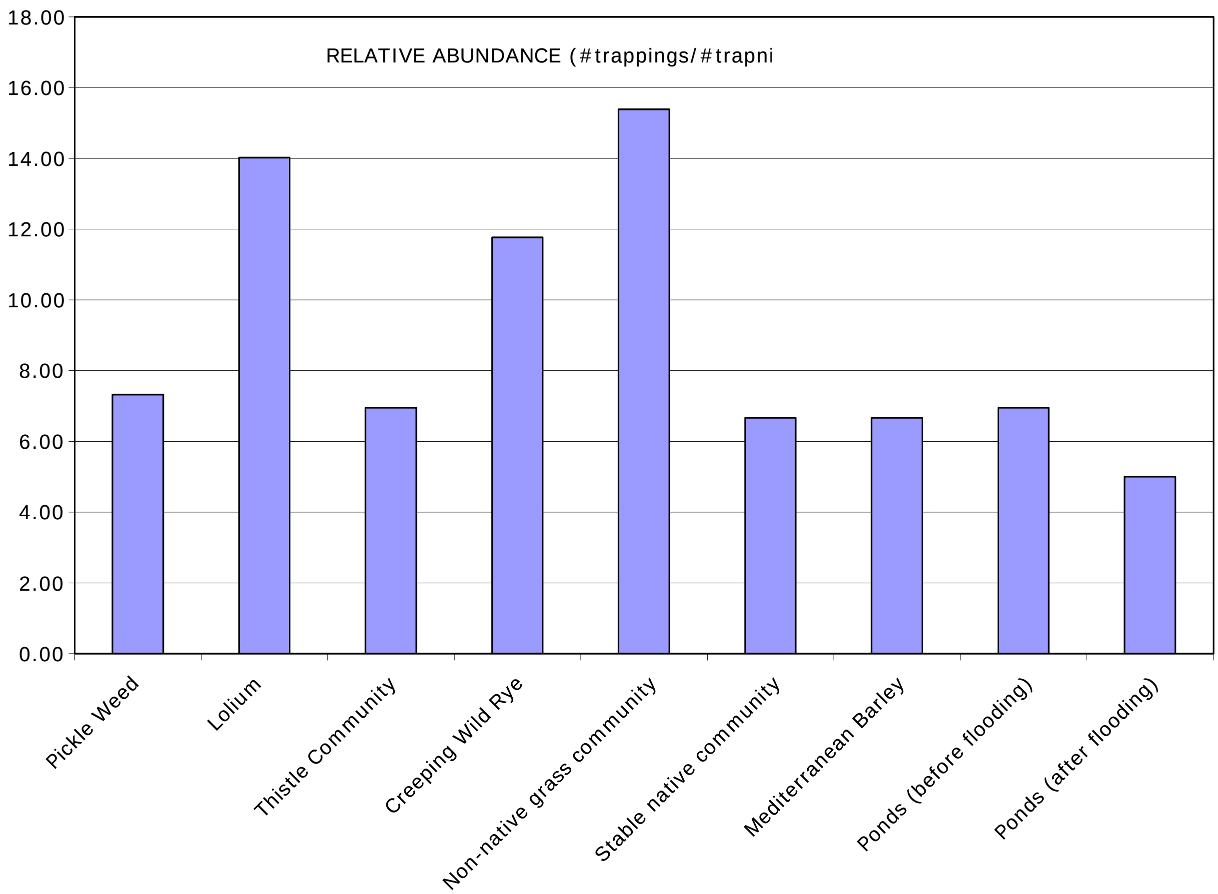



Figure 27. Relative abundance of small mammals in various habitat types.

Analysis of species diversity revealed interesting patterns as well. We found very low species diversity in non-native grass community, and in the non-native thistle community where we found only one species, the California vole. The mixed native community supported the highest species diversity and did not support the non-native house mouse (Figure 26).

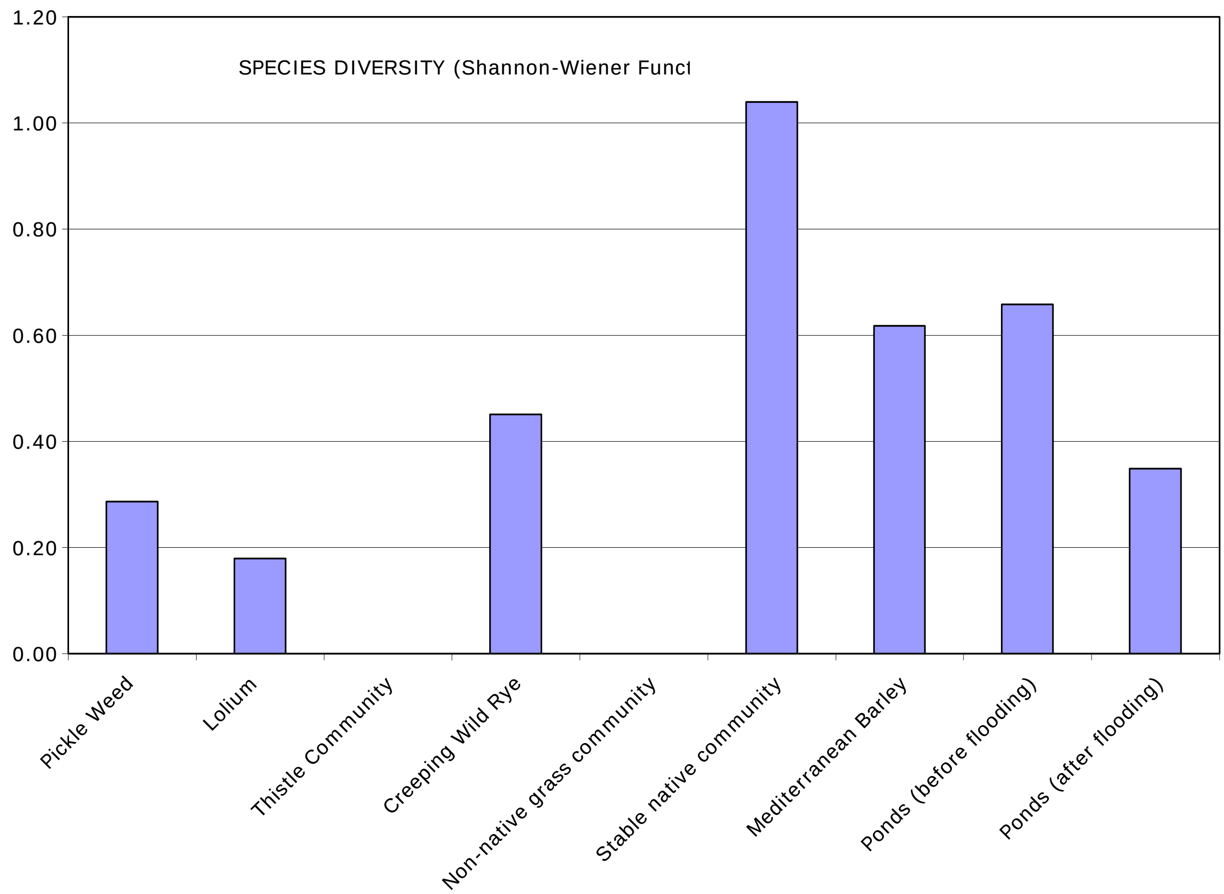



Figure 28. Small mammal species diversity in various habitat types.

We conducted additional surveys, which while more limited in scope, targeted very specific monocultural stands surrounded by mixed stands of native and non-native plants. This allowed us to fine tune the results of the habitat surveys to identify microhabitat use within these larger plant communities. These date are summarized by species (Figures 27 & 28).

The most abundant rodent at the Moro Cojo floodplain site is the California Vole, and this is quite likely due to a high level of plasticity in habitat use. We found voles at relatively high abundances in all four vegetation types (Figure 27). We also found house mice in all four vegetation types, though at lower abundances. The California deer mouse appeared to be the most rigid in their use of these four vegetation types, appearing only in the yellow lupine, completely absent from stands of spike rush, creeping wild rye, and Italian rye, but deer mice were the most abundant in stands of yellow lupine (Figure 28).

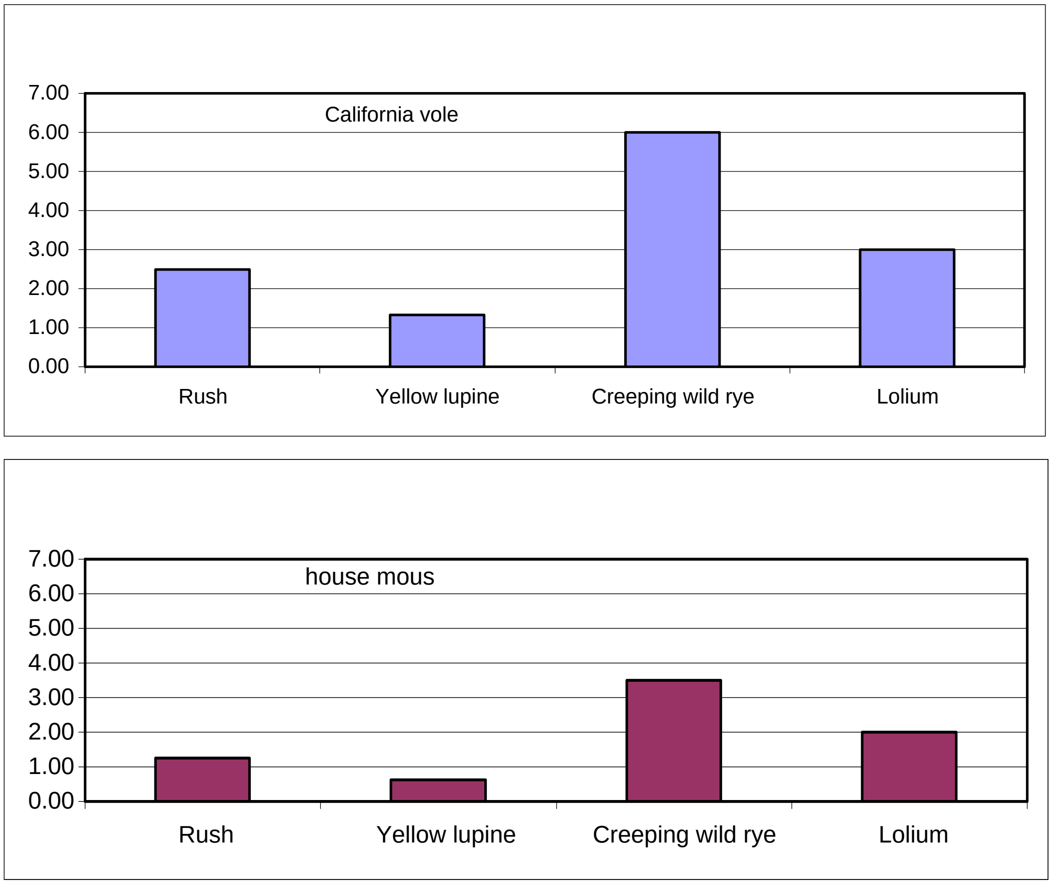
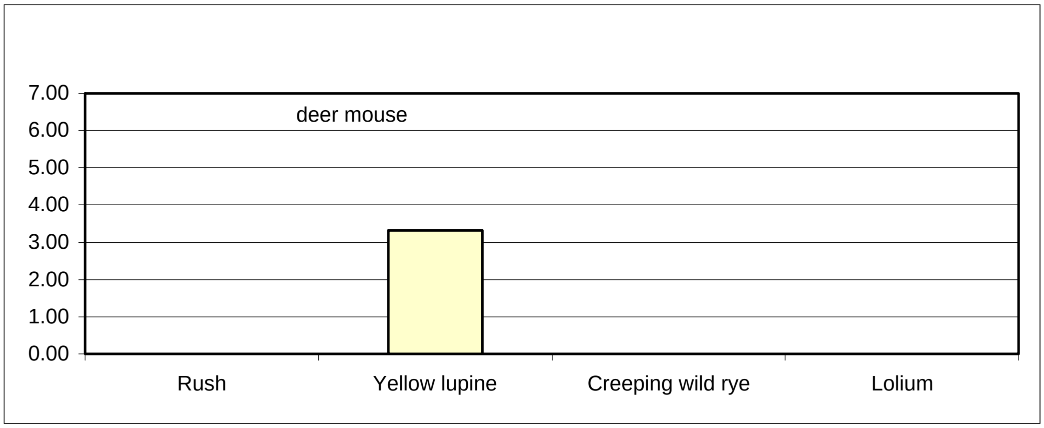



Figure 29. Abundance of California vole and house mouse among various plant types.

The results for the harvest mouse were very encouraging. We found that harvest mice were relatively abundant in stands of spike rush (Figure 28). The southern harvest mouse (*Reithrodontomys megalotis limicola*), a relative of the local sub-species is a species of special concern in California (ASM 2004) and the status of the central California coast population is unknown, but may be in decline. The decline of this species appears to be the result of loss of habitat to agriculture, grazing, and degradation of habitat. The return of native habitats appear to have been directly beneficial to this species, and we have expanded stands of spike rush from a few square yards to almost 2 acres, increasing a habitat that supports this species, by several orders of magnitude. We have never found this species in surveys of agricultural field so they do not appear to be a crop damaging species.



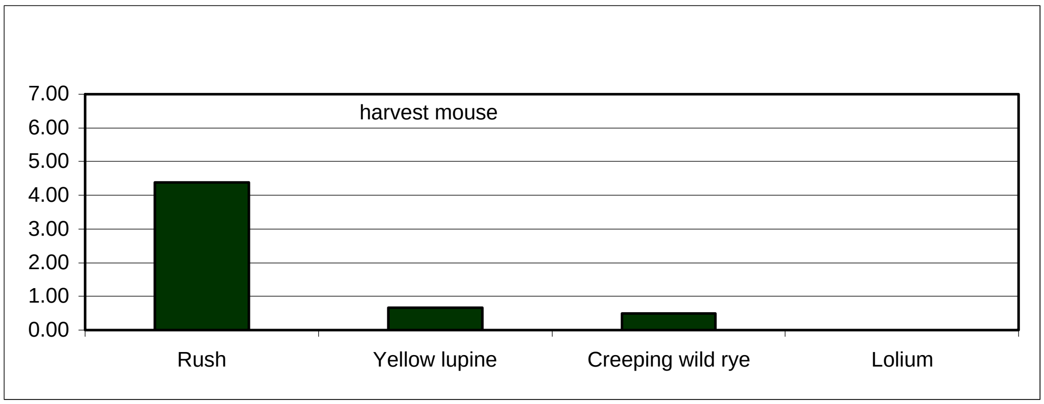




Figure 30. Abundance of deer mouse and harvest mouse among various plant types.

We used the results of the small mammal monitoring to identify restoration strategies that would be compatible with agricultural operations. We repeatedly mowed very large areas of non-native grasses and weeds along the farm/Moro Cojo floodplain site border to increase the effectiveness of visual predators, primarily raptors and egrets. We restored large areas of native vegetation that we had identified as not supportive of unusually large populations of rodents, we built ponds, and removed stands of non-native vegetation that supported high numbers of rodents.

Our restoration of native wetland and dry upland plant communities and ponds at the Tottino Ponds and Moro Cojo floodplain site has resulted in a very significant reduction of pest rodent problems along both edges of the adjacent farms. In fact, both farms have reduced, and in most areas eliminated, the application of rodenticides, which had been used extensively in the past. This was a major concern of the farmers as the restoration sites were converted from agricultural/ rangelands, to native wetlands. This concern has been thoroughly addressed to the great relief of both Sunset and Seamist farms.

We plan to compile the information from the small mammal habitat studies along with information on the success we are having in reducing the impacts of rodents on crops and produce an informational document that can be distributed to the growers so that they can start to use these habitat management tools for dealing with these types of problems. Riparian and wetland restoration can provide a very direct benefit to these farmers. As more and more farmers become aware of this, the interest in participating in, and even initiating, these types of projects will increase.

We also kept records on incidental sightings of mammals occurring at the Moro Cojo and Tottino ponds sites. These are listed in Table 13.

Table 13. Mammals observed at the Tottino Ponds and Moro Cojo floodplain restoration sites.

| **Common Name** | **Species** | **Native Species** |
|---|---|---|
| California vole | *Microtus californicus* | √ |
| Deer mouse | *Peromyscus maniclatus* | √ |
| Western harvest mouse | *Reithrodontomys megalotis* | √ |
| House mouse | *Mus musculus* | |
| Beechey ground squirrel | *Ammospermophilus beechyi* | √ |
| Brush rabhit | *Silvilagus audoboni* | √ |
| Muskrat | *Ondatra zibethicus* | √ |
| Mule deer | *Odocoileus hemionus* | √ |
| Long-tailed weasel | *Mustela frenata* | √ |
| Red fox | *Vulpes vulpes* | |
| Coyote | *Canis latrans* | √ |

Vegetation Monitoring

Results of vegetation monitoring was covered extensively in the *Native Plant Establishment and Weed Control* section. This section will address a more detailed description of plant species composition.

Monitoring vegetation had two main components, mapping of areas dominated by native vegetation and compiling a species list of all of the vegetation. When we began this project, 90 to 95% of the Moro Cojo site was dominated by non-native vegetation. The vast majority of the lower lying areas were nearly 100% occupied by Mediterranean barley and Italian rye, interspersed with large patches of curly dock, bull thistle, poison hemlock, mustard, radish, and other weedy species. Weeds along the upland areas adjacent to the farm had been long advantaged by overspray by irrigation sprinklers. Large-leafed herbaceous species interspersed with rip-gut brome completely dominated, covering these areas in a 3-4 foot tall thicket.

Repeated treatment of large areas of the site by mowing, hand-pulling, and repeated flooding and drying (in the ponds), has resulted in a significant shift in the co-dominance of native and non-native vegetation. By the end of the project we mapped over 40 acres where native plant communities or individual species dominated (Figure 13; Table 4). The dominant plants in the low wet areas are meadow barley, salt clover (formerly thought to be extinct), spike rush, salt grass, pickleweed, and salt brush. The areas were water is ponded are dominated by spike rush, California tule, bulrush with stands of arroyo willow and cottonwood along the floodplain edge.

In addition to GIS mapping the larger native vegetation communities we have conducted annual botanical surveys of the 200-acre site. These surveys were conducted during the spring of each year, and the species list was augmented by incidental discoveries of plants that had not occurred or had not previously been recorded at the site. A complete list of plant species identified to date it provided in Table 14.

Table 14. Plant species identified at the Moro Cojo floodplain site.

| Scientific Name | Common Name |
|---|---|
| *Acer negundo* | Box elder |
| *Aira caryophyllea* | Silvery hair grass |
| *Amsinckia menziesii var. meziesii* | Harvest fireweed |
| *Amsinkia menziesii var. intermedia* | Common fiddleneck |
| *Anagallis arvensis* | Scarlet pimpernel |
| *Atroplex patula* | Spear saltbrush |
| *Baccharis pilularis* | Coyote brush |
| *Brassica sp.* | Mustard |
| *Bromus catharticus* | Rescue grass |
| *Bromus diandrus** | Ripgut brome |
| *Bromus hordeaceus* | Soft chess |
| *Calandrinia ciliata* | Red Maids |
| *Capsella bursa-pastoris* | Shepherd's purse |
| *Carduus pycnocephalus* | Italian thistle |
| *Chamomilla suaveolens* | Pineapple weed |
| *Chenopodium album or berlandieri* | Lamb's quarter |
| *Cirisium vulgare* | Bull thistle |
| *Claytonia perfoliata* | Miner’s lettuce |
| *Conium maculatum* | Poison hemlock |
| *Conyza canadensis* | Horseweed |
| *Cotula coronipifolia* | Brass buttons |
| *Cryptantha leiocarpa* | Coast Cryptantha |
| *Cuscuta salina* | Salt marsh dodder |
| *Digitaria sanguinalis* | Crab-grass |
| *Distichlis spicata* | Salt grass |
| *Downingia puchella* | Flat-faced dowingia |
| *Eleocharis macrostachya* | Spike rush |
| *Elymus trachycaulus ssp. Trachycaulus* | Creeping wild rye |
| *Epilobium ciliatum* | California willow-herb |
| *Erodium cicutarium* | Red-stemmed filaree |
| *Erodium moshatum* | White-stemmed filaree |
| *Eschscholzia californica var. californica* | California poppy |
| *Frankenia salina* | Alkali heath |
| *Galium parisiense* | Wall bedstraw |
| *Geranium dissectum* | Cut-leaved geranium |
| *Grindelia latifolia* | Coastal gum plant |
| *Helenium puberulum* | Sneezeweed |
| *Heliotropium curassavicum* | Chinese parsley |

Table 13 (Cont)

| Scientific Name | Common Name |
|---|---|
| *Hordeum brachyantherum* | Meadow barley |
| *Hordeum marinum ssp. Gussoneanum* | Mediterranean barley |
| *Hordeum murinum* | Barnyard foxtail |
| *Jaumea carnosa* | Fleshy jaumea |
| *Juncus bufonius* | Toad rush |
| *Juncus bufonius* | Common toad rush |
| *Juncus mexicanus* | Mexican rush |
| *Juncus occidentalis* | Western rush |
| *Juncus xiphioides* | Iris leaf rush |
| *Lactuca serriola* | Prickly lettuce |
| *Lasthenia californica* | Coast goldfields |
| *Lasthenia minor* | Goldfields |
| *Lemna minor* | Lesser duckweed |
| *Lepidium latipes* | Dwarf peppergrass |
| *Lepidium pinnatifidum* | Pepper-grass |
| *Leymus triticoides* | Beardless ryegrass |
| *Limosella acaulis* | Mudwort |
| *Lobularia maritime* | Alyssum |
| *Lolium multiflorum* | Italian ryegrass |
| *Lolium perenne* | Perennial rye |
| *Lotus corniculatus* | Bird's foot trefoil |
| *Lupinus arboreus* | Yellow bush lupine |
| *Lupinus nanus* | Sky lupine |
| *Lythrum hyssopifolium* | Brass poly |
| *Malva nicaeensis* | Bull mallow |
| *Marrubium vulgar* | Horehound |
| *Medicago polymorpha* | Bur clover |
| *Melilotus indica* | Sour clover |
| *Melilotus indica* | Indian melilot |
| *Parapholis incurva* | Sickle grass |
| *Picris echioides* | Bristly ox-tongue |
| *Plantago coronopus* | Cut-leaved plantain |
| *Plantago lanceolata* | English Plantain |
| *Plantago subnuda* | Naked Plantain |
| *Poa annua* | Annual bluegrass |
| *Polygonum arenastrum* | Common knotweed |
| *Polygonum lapathifolium* | Willow weed |
| *Polypogon maritimiss* | Maritime bearded grass |
| *Polypogon monspeliensis* | Rabbitfoot grass |
| *Potentilla anserina ssp. pacifica* | Pacific silverweed |
| *Quercus agrifolia* | California live oak |

Table 13 (Cont)

| Scientific Name | Common Name |
|---|---|
| *Raphanus raphanistrum* | Jointed charlock |
| *Raphanus sativus* | Wild radish |
| *Rumex acetosella* | Sheep sorrel |
| *Rumex conglomerates* | Clustered dock |
| *Rumex crispus* | Curly dock |
| *Rumex obtusifolia* | Bitter Dock |
| *Salicornia virginica* | Pickleweed |
| *Salix lasiolepis* | Arroyo willow |
| *0Salix lucida ssp. lasiandra* | Yellow willow |
| *Scirpus californicus* | California Tule |
| *Scirpus maritimus* | Bulrush |
| *Silybum marianum* | Milk Thistle |
| *Sisymbrium officinale* | Hedge mustard |
| *Sonchus oleraceus* | Common sow thistle |
| *Spergularia marina* | Salt-marsh sand spurry |
| *Spergularia rubra* | Purple sand spurry |
| *Stachys adjugoides* | Bugle hedge nettle |
| *Stellaria media* | Common chickweed |
| *Taraxacum officinale* | Common dandelion |
| *Trifolium depauperatum var. hydrophilum* | Salt clover (Sac clover) |
| *Trifolium fucatum* | Sour clover |
| *Trifolium microdon* | Valparaiso clover |
| *Trifolium wormskioldii* | Cow clover |
| *Triphysaria eriantha ssp. rosea* | Johnny tuck |
| *Triphysaria versicolor* | Smooth owl's clover |
| *Typha latifolia* | Broad-leaved cattail |
| *Urtica urens* | Dwarf nettle |
| *Vulpia bromoides* | Six week fescue |
| *Xanthium spinosum* | Spiny clotbur |

Invertebrates

We monitored benthic invertebrates and plankton communities at both the Tottino Ponds and Moro Cojo floodplain site. We collected replicate (2- 6) sediment samples with a standard area corer in each pond (1-5), and in pond subhabitats (shallow edges, deep central pond, and pond-edge vegetation). Sediment was washed over 0.5 mm screens to capture benthic invertebrates. Water column samples were also collected using a 0.5 mm screen.

We discovered that water boatman, amphipod and ostracod crustaceans, fly larvae, oligochaete worms, and gastropods dominated the pond benthos. Many species of insect larvae also colonized the ponds. We found that the water flow also favored a rich zooplankton community dominated by the crustaceans, cladocera (Daphnia) and copepods (Figure 31; Appendix E).

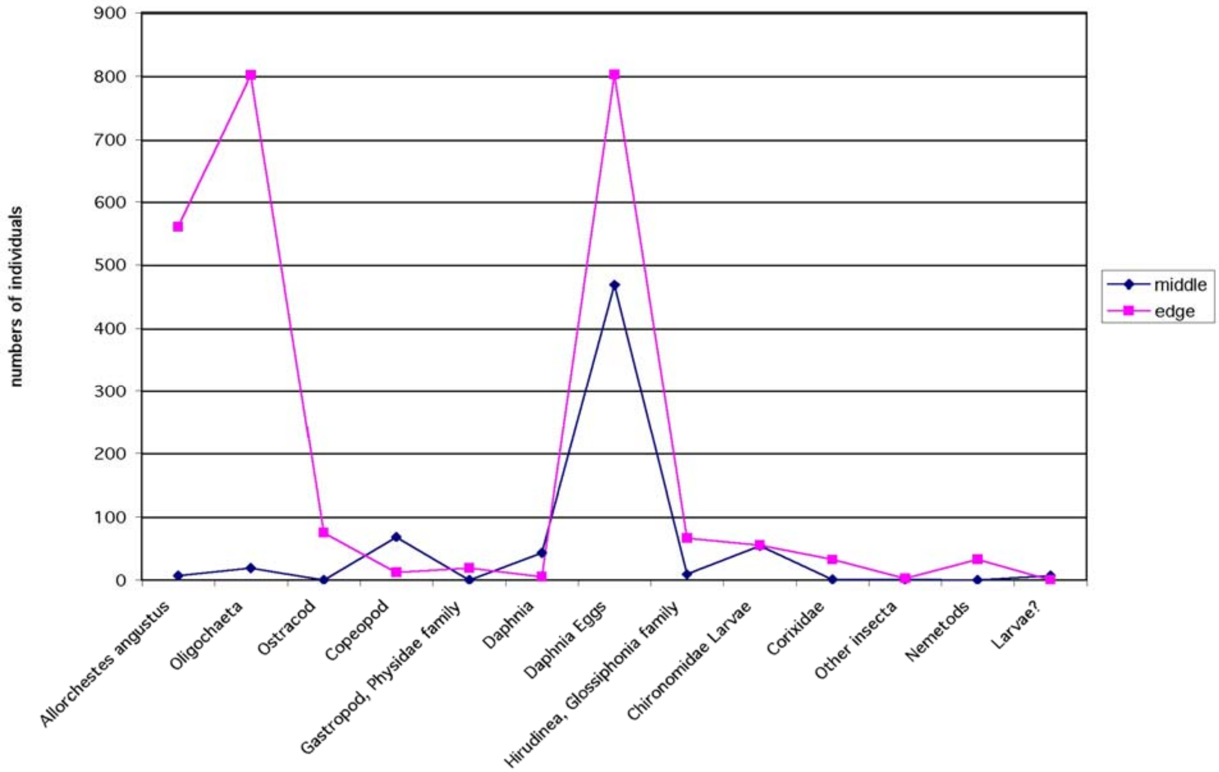



Figure 31. Relative abundance of invertebrates surveyed at Tottino Ponds.

After the ponds had been full of water for several months – we found no mosquito larvae in quantitative samples or in more extensive qualitative sampling throughout the pond system as we expected. This is for the most part due to the fact that the water levels in the ponds are allowed to go through a repeated drying/wetting cycle. Secondly, both of these areas are exposed to fairly consist winds, which creates conditions unsuitable for mosquito larvae. The hydrology continues to favor the crustacean zooplankton community (cladocerans and copepods). Finally, since the ponds are hydraulically linked to each other through channels or through breaches in the berms, as each pond was developed it was supplied with a wide variety of colonists (both plants and animals) from the source ponds. Thus, water that runs into these ponds carries with it both seeds and invertebrates. Therefore, the succession of invertebrates was more rapid in the later ponds, than in the earliest ponds, which were established in an area formerly dominated by seasonally flooded grasslands.

In July/August 2000, mosquito fish were added to the Tottino Ponds by Monterey County Mosquito Abatement. After discussions with Mosquito Abatement staff in which we demonstrated that mosquito were not breeding at the ponds, we completely dried the ponds in order to remove the mosquito fish during the fall of 2001. Before the remaining pools were pumped to remove the fish, the fish had eaten the large zooplankton and rotifers (a small zooplankton) became the dominant animal. With these non-native fish removed, the crustacean zooplankton again flourished, as did extremely large Daphnia. Since there is currently no mosquito problems in Tottino Ponds, mosquito fish have not been re-introduced. Future plans include restoration of native fish populations; for now we will let native birds consume the benthic and planktonic invertebrate production.

Our observations indicate that we can maximize the number of invertebrates, and subsequently birds, in the Tottino Ponds by filling the system in 2-3 days, letting it gradually recede for 2-3 weeks, and then repeating the fill cycle. If the system is kept full longer or kept drier, the diversity of invertebrates and birds decreases. At first we did not maintained an optimal hydrologic cycle for invertebrate communities because of the need to dry areas for weed control, mosquito fish removal, and construction. We have now completed the last major mowing and pipe installation so this has allowed us to maintain this optimal hydrographic cycle without interruption.

After draining and refilling the ponds, we found that there were many wet colonization sources that were not present the first time the ponds were filled. As a result, the benthic invertebrate communities – particularly the planktonic ecosystem - developed much faster during the second year compared to the first year after the initial pond construction. For example, the amphipod crustaceans *(Allorchestes*) did not become abundant until the second year of colonization after pond construction.

We will continue to monitor invertebrate communities in conjunction with future studies of the interactions with native fish and native invertebrates.

Point Photographs

CEC obtained SWRCB guidelines for point photographs In June 2001. Photos were taken according to those guidelines at least once a year, in the mid or late spring and even the early summer. Photographic points were selected, marked, and GPS locations were determined in the Fall of 2001. We collected photographs of the restoration sites, as well as additional photographs that effectively demonstrate the results and techniques of the restoration.

Pond C 2001 – Moro Cojo Floodplain Site


Pond C 2002 – Moro Cojo Floodplain Site


Pond C – 2003, Moro Cojo Floodplain Site


Pond I 2001 – Moro Cojo Floodplain Site

Pond I 2002– Moro Cojo Floodplain Site

Pond I 2003 – Moro Cojo Floodplain Site


Tottino Ponds 2001

Tottino Ponds 2002

Tottino Ponds 2003

**Task 8  Draft and Final Report**

This document completes Task 8

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Appendix A – TAC Members and Attendance

Appendix B – Permits

Appendix C – Moro Cojo Preferred Plan

Appendix D – Water Quality Monitoring Field Data Sheets and Lab Data

Appendix E – Invertebrate Survey Data