

# **Habitat Restoration Monitoring & Assessment: A Personal Geodatabase Design**

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## **Abstract**

Conservation organizations are increasingly looking to assess the effectiveness of their habitat restoration activities. Such analyses require an accessible record of land use and restoration activities over time. To address these needs in a complex, multi-institutional land conservation and restoration initiative in Central California, we custom designed an ArcGIS 9.1 personal geodatabase to house spatial and empirical records of 20 years of habitat restoration implementation, monitoring and research at a large (40,000 acre) preserve in California's Sacramento Valley on the edge of the Sacramento River Delta. The resultant dataset was used to assess the effectiveness of various habitat restoration activities.

## **Introduction**

The Cosumnes River Preserve is a watershed-scale, multi-agency collaborative project with the goal of cooperatively managing lands within the Cosumnes River watershed as a single ecological unit for the protection, restoration, and maintenance of the quality and diversity of two California ecological communities: valley oak (*Quercus lobata*) riparian forest and freshwater seasonal wetlands (CRP 2007). The Nature Conservancy and its partners established the Cosumnes River Preserve in 1987 with 1,480 acres; it now encompasses more than 40,000 acres (CRP 2007).

The Cosumnes River Preserve partners have implemented a number of restoration projects and vegetation management activities in pursuit of conserving and restoring riparian habitat types along the Cosumnes River. Riparian habitat types within California's Central Valley are a priority for conservation and restoration (CALFED 2000), as this habitat covers less than 5% of its original extent (Hunter *et al.* 1999). Riparian habitat restoration efforts at the Cosumnes River Preserve have been both active and semi-passive in nature. Active restoration involves the direct planting of desirable plant species, while semi-passive restoration is achieved by manipulating the structure of existing man-made features influencing physical processes such as flood regimes through, for example, setbacks or intentional breaching of levees. Passive restoration of riparian habitat, if effective, is less labor-intensive and therefore more cost-effective than active restoration when implemented on a large scale. Active restoration methods provide greater control over the species planted, and are common in small-scale habitat restoration.

Monitoring has taken place intermittently at a variety of restoration sites and reference sites (sites considered to have reached a natural "climax" community, which serve as references for the end goal of restoration sites). These monitoring efforts were neither systematic nor coordinated, however, and their results were never compiled. We compiled these data into a geodatabase to allow a meta-analysis comparison of the outcome of active versus passive restoration.

This paper details the creation and structure of a personal Access geodatabase designed in ArcGIS 9.1 to record and analyze restoration activities and vegetation monitoring data collected throughout the 20 year history of the Cosumnes River Preserve.

## **Methods**

### **Step 1: Literature and Data Review**

We reviewed all vegetation-related records from the last 20 years of management (1985-2005) at the Cosumnes Research Preserve (CRP). These data were in the form of notes, reports, dissertations, publications and personal communications with reserve managers. In total, we reviewed twenty-three written documents, three existing shapefiles, and personal communications with four key individuals. We attributed lists of species planted, methods of planting, irrigation, weed control and herbivory protection, percent

germination by species, and percent survival by species for 76 separate restoration locations.

## **Step 2: Spatial and Empirical Data Entry**

Data collected from our review process were used to create geodata layers covering restoration activities and monitoring during these 20 years. During this review, all relevant data were entered into tables in Microsoft Access and/or ArcGIS feature classes within the same Access personal geodatabase. Due to the variable nature of data collected from these many sources, individual tables and feature classes were created for each different data source, and often multiple tables and/or feature classes were created for different data from a single source. Data were entered into Access tables noting spatial reference (site name), source of the data, estimation of data accuracy (e.g. objective measurement or subjective approximation), and the data itself. Feature classes either contained the data themselves or, more often, referenced data entered into tables via a common site code.

We used no topology rules, as we did not need to restrict overlaps or gaps between features among layers. Many researchers recorded data in overlapping areas, and our goal was to record, as best as possible, the spatial extent of all individual research locations as well as to enter the associated data into Access.

We used neither relationship classes (in ArcCatalog) nor table relationships (in Microsoft Access). All linking of tabular data to spatial data was done using attribute joins in ArcMap or using queries in Access.

## **Step 3: Spatial Metadata Structure**

Analysis of vegetation data collected for different purposes and within different spatial extents required establishment of metadata structure. We chose create a spatial metadata structure by creating standardized site boundaries for restoration sites and reference sites, and summarizing input datasets to fit into this metadata structure. The standardized site boundaries thus served as a common denominator to allow analysis of vegetation change over time (Figure 1). The resulting spatial data included 71 polygons covering nearly 3000 ha (29.8 km<sup>2</sup>).



Figure 1. Standardized restoration site and reference riparian forest site feature classes created for meta-analysis of vegetation monitoring data. Sites labeled as containing restoration planting records have empirical data associated with them in a linked data table, as described in Step 4).

#### **Step 4: Standardize Spatial Scale**

Summarization of data to fit into these standardized site boundaries was difficult due to the fact that none of the 20 years of vegetation monitoring had been coordinated with a meta-analysis or shared experimental design. We used a series of calculations in ArcMap and/or queries in Access to extrapolate those values collected in the field by researchers to make these data results appropriate to the standardized site boundaries. Our knowledge of the landscape, use of aerial imagery, and consultation with original researchers was invaluable in allowing us to accomplish this standardization.

#### **Step 4: Empirical Metadata Structure**

Data were collected by a variety of researchers who collected data for different purposes using a variety of methods, parameters, time scales and spatial scales. We included all parameters collected in our data tables, and included columns to indicate methods and units of data collection.

A single data table was used to collect all empirical data from all vegetation and restoration records from all years. This table (Figure 2) uses a combination of four columns as a primary key. These columns are year, reference site code, species code, and canopy layer. Combined, these four columns define the time, location and vegetation to which the data are referring.

Field Name	Data Type	Description
ID	AutoNumber	
Year	Number	water year to which this record refers (October 1 - September 31, with water year referring to the Jan-Sept. 31 year)
SiteCode	Text	restoration site code
SpCode	Text	species code (generally first two letters of genus & species)
CanopyLr	Text	canopy layer (descriptions: n.g. seedling, inventory, all)
SpPctCode	Text	code to link refer to tblSpPctRecords
BA	Number	basal area per unit area
BAAcc	Text	degree of accuracy of data provided, based on source (expert opinion, inventory, sample)
BAIn	Text	number of plants sampled to calculate basal area ('all' indicates full inventory)
BAUnit	Text	basal area data provider
BAUnit	Text	area per area unit of basal area
BAUnit	Text	degree of accuracy of data provided, based on source (expert opinion, inventory, sample)
BAUnit	Number	average basal area per tree
BAUnit	Text	north when basal area per tree was measured
BAUnit	Text	number of plants sampled to calculate basal area per tree ('all' indicates full inventory)
BAUnit	Text	basal area data provider
BAUnit	Number	standard deviation of basal area per tree sample measurements
BAUnit	Text	unit of basal area per tree measurements
BAUnit	Number	variation of basal area per tree sample measurements
BrowAcc	Text	degree of accuracy of data provided, based on source (expert opinion, inventory, sample)
BrowIn	Text	number when browse damage was monitored
BrowIn	Text	number of plants sampled to calculate browse ('all' indicates full inventory)
BrowIn	Number	% of plants subject to browsing damage
BrowIn	Text	browse data provider
CovAbt	Number	absolute % cover
CovAcc	Text	degree of accuracy of data provided, based on source (expert opinion, inventory, sample)

Field Name	Field Properties
Year	Field Size: 50 Format: Input Mask: Caption: Default Value: Validation Rule: Validation Text: Required: No Allow Zero Length: Yes Indexed: No Unicode Compression: Yes OLE Mode: No Control OLE Database Mode: None Smart Tag:

Figure 2. Microsoft Access data table used to record site, year, canopy layer and species-specific restoration and monitoring records.

## Step 5: Meta-analysis

Once data were standardized, a meta-analysis of vegetation change and restoration success over time was conducted using data from selected reference sites (mature riparian forests) and restoration sites. Data analysis was done in a Microsoft Access environment using non-spatial queries, rather than in an ArcMap environment (Figure 3).

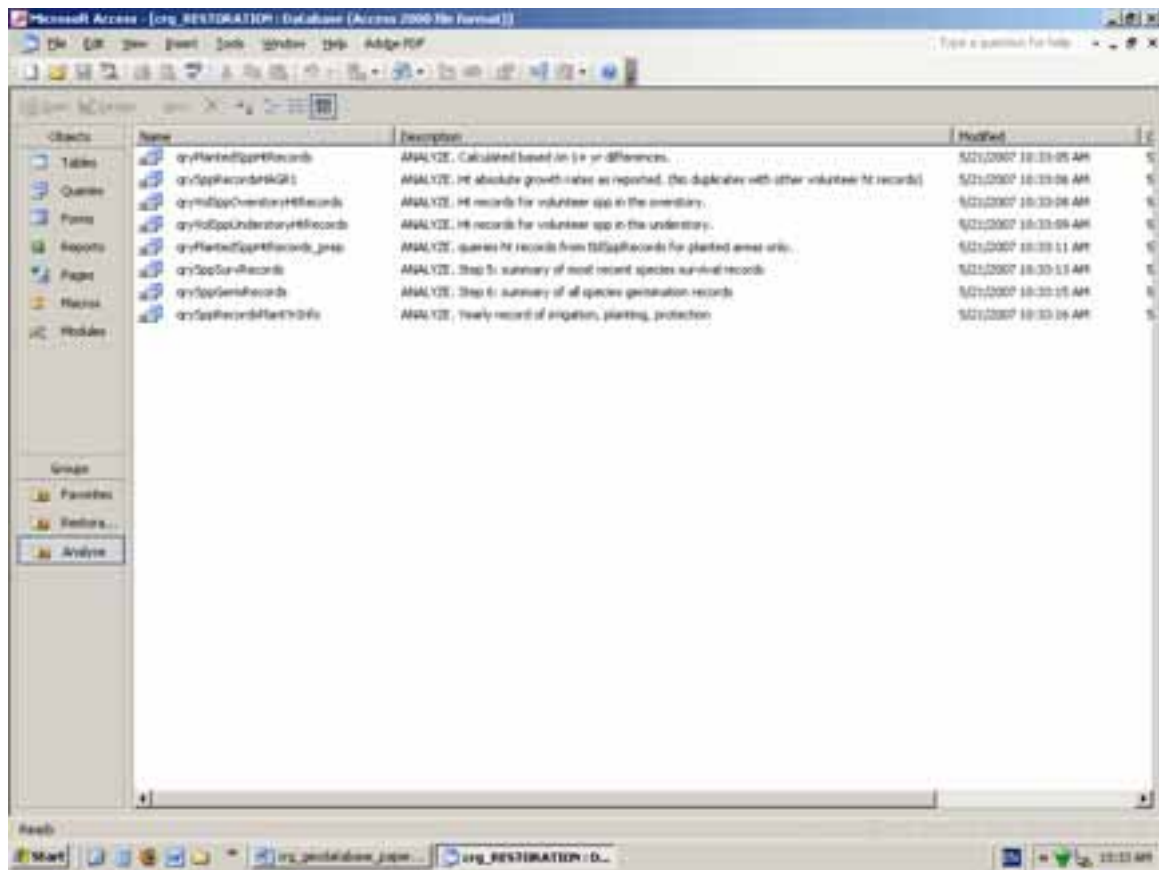


Figure 3. Series of queries developed for meta-analysis of vegetation species data across multiple sites and multiple years. Empirical data were linked to spatial sites via a common site code.

Data compilation for analysis was done in Access rather than in ArcGIS in order to allow a one-to-many relationship between the spatial data (features within a polygon feature class) and the empirical data (multiple rows of data – including unique year, species and canopy layer data – per feature). The relationships between tables are shown in Figure 4.

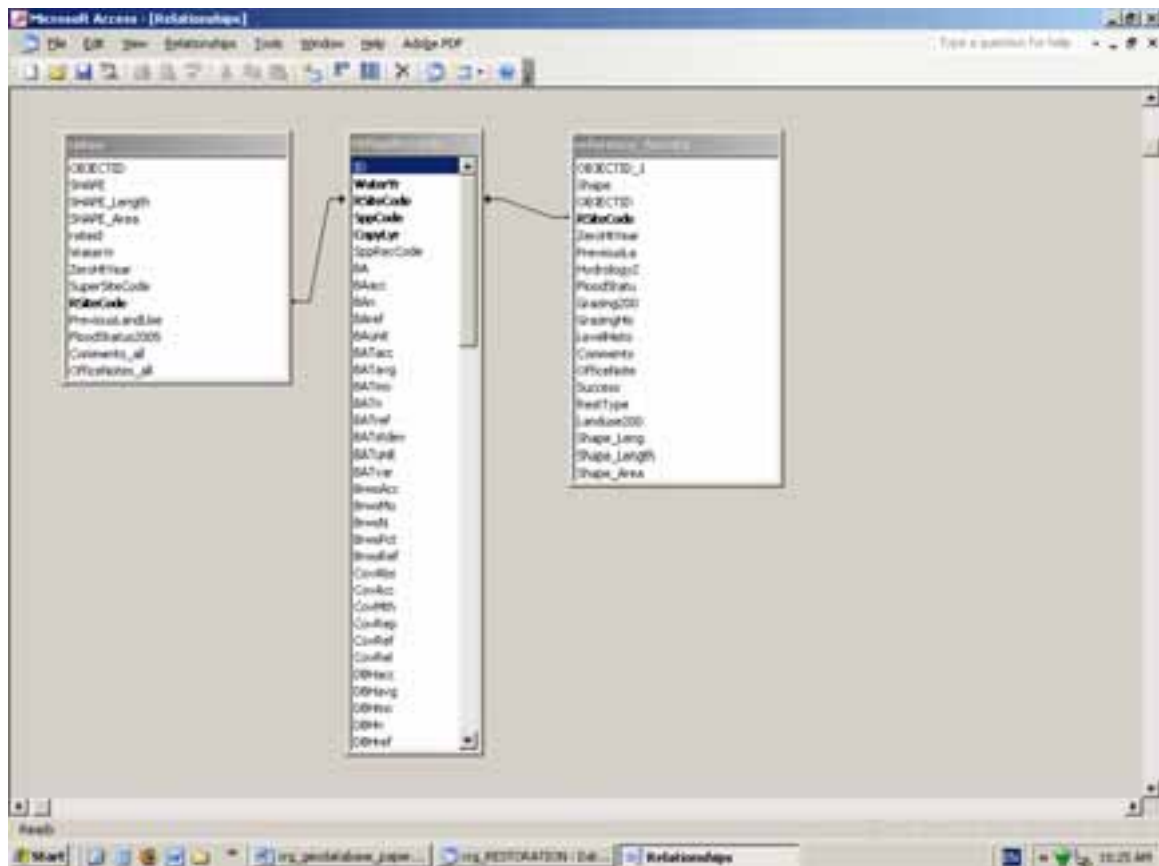


Figure 4. One-to-many relationships between feature classes (rsites and reference\_forests) and empirical data (tblSpRecords).

Creating of Access queries to summarize data for analysis was also useful in allowing access to the query data in JMP (SAS 2005) statistical software via an OLE DB database connection.

## Step 6: Reports

One of the many advantages of using a personal Access geodatabase is the ability to create reports which are automatically updated when integrated feature class or table data are modified. We created a report to summarize planting and survival records by species (Figure 5).



**Planting Records by Species**

Restoration Site	Initial Planting (Yr)	Replanting (Yr)	Latest Survival Monitoring (Yr)	Survival
<b>Alnus rugosus</b>				
CASTNW	2002		2003	2%
DUSLOUGH	1999		1996	0%
Green	1992		1992	0%
Red	1992		1992	0%
THGBOII	2000		2001	0%
<b>Alnus incana</b>				
DUSLOUGH	1999		1996	0%
<b>Cornus sericea</b>				
CASTNW	2002		2003	1%
<b>Fraxinus latifolia</b>				
CASTNW	2002		2003	17%
Green	1992			na
LSE	1996			na
MACWORLD	1991			na
NC	1991			na
Red	1992			na
TRALHO	1990		1998	73%
VCH	1991		1992	93%
<b>Rubus californicus</b>				
ESSW	1991			na

Figure 5. Report created in Microsoft Access to summarize planting records for individual feature classes (restoration sites).

## Results

Construction of this geodatabase allowed us to efficiently enter data from a variety of sources, visualize and record the spatial extent and overlap of data sources, maintain data integrity, and conduct a meta-analysis of 20 years of restoration and monitoring data. The results of our analyses of oak growth rates and other responses to active versus passive restoration are available in a report prepared for CALFED (Viers *et al.* 2006).

## Conclusion

Evaluation of habitat restoration requires multi-scale monitoring of biological data over space and time. The authors recommend a personal Access geodatabase as a suitable structure for managing such data. A geodatabase eases the processing of data for meta-analysis by providing a manageable structure for the compilation and standardization of disparate data sources. A personal Access database combines the advantages of ArcMap and Microsoft Access into a single container for the entry, visualization, organization, processing, storage, analysis, and reporting of spatial and empirical data. By assimilating both spatial and empirical data into a single geodatabase, managers may be better enabled to analyze existing data and design future data collection efforts for meta-analysis.



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