NatureServe Vista

Software for Biodiversity Planning

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Abstract

NatureServe Vista is an ArcMap 9.0 extension to assist conservation and land-use planners in incorporating biodiversity. The system allows users to assemble a rich database of conservation targets (elements of biodiversity) including distribution over the planning region, occurrence viability, confidence and compatibility with relevant land-use or land-management practices. Biodiversity elements can then be categorized, weighted and assigned goals according to a wide array of stakeholder values. Aggregated conservation value across the planning region is then a function of a selection of elements and their weight according to one such stakeholder. Interactive tools allow users to understand the biodiversity composition of individual planning units. Existing conditions and land-use plans are easily imported and evaluated for their performance against stakeholder goals. Users can export reports in HTML to facilitate feedback from constituent groups. The system requires ArcView 9.0 with Spatial Analyst, is currently in beta, and scheduled for final release late 2004.

The Problem

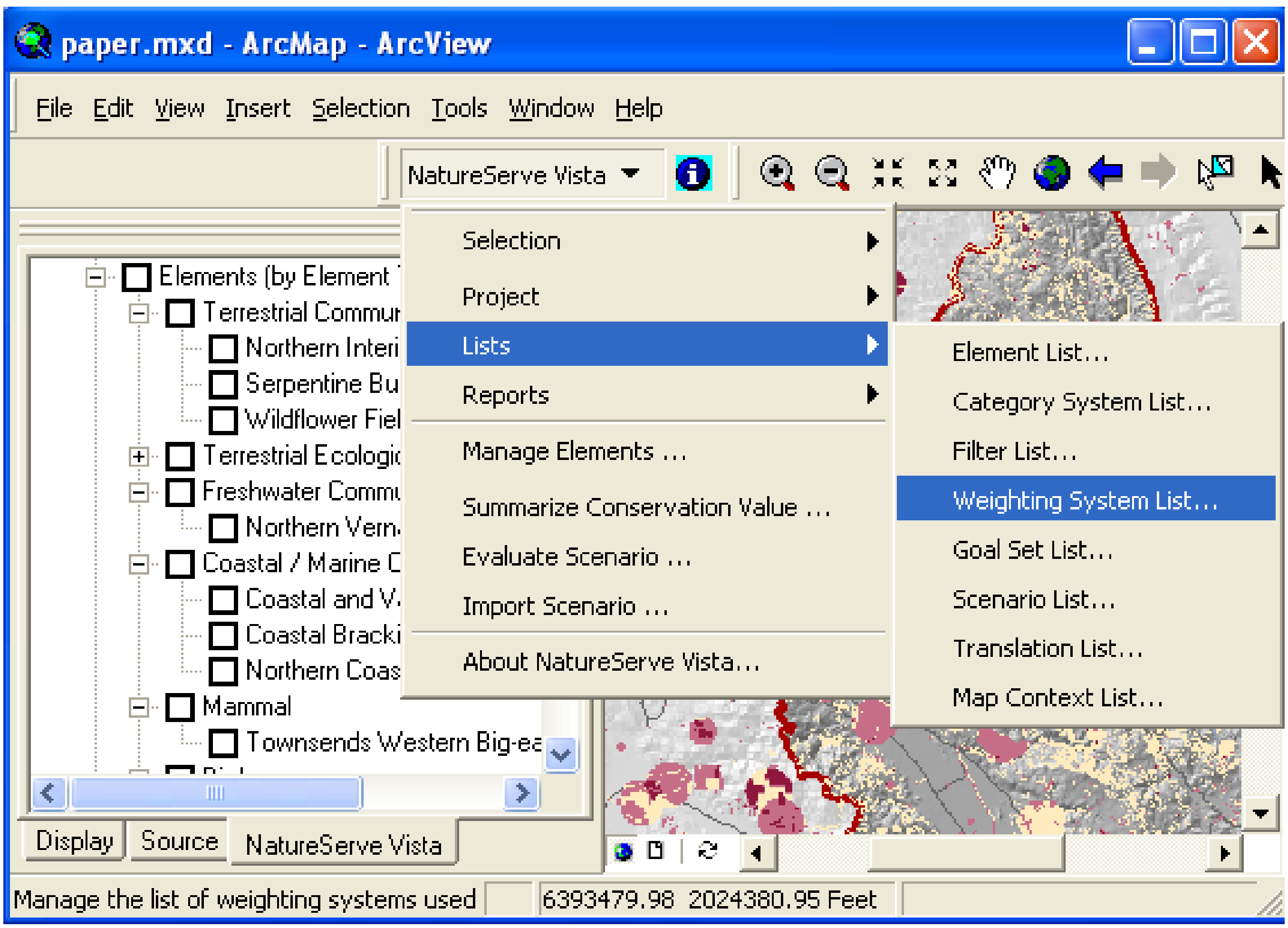
Across the globe, communities are struggling with the complex task of balancing environmental protection and economic growth to enhance their quality of life. The bottom line demonstrates the importance of these concerns. In 2002 alone, U.S. voters approved an astounding $10 billion in public funds for open space protection and land acquisition through local and state ballot initiatives. How will all that money be spent? Will it be invested wisely, used to conserve the most important lands that meet community goals for open space, recreation, scenic vistas, and watershed protection, while also meeting the habitat needs of wildlife?

Much of the answer will depend upon how thousands of policy makers, including local and regional planners, state officials, land trusts, and world-wide non-governmental organizations, go about making their decisions about which places to protect. These decision-makers will need reliable, scientifically accurate information about habitats and species, delivered in an understandable and accessible format, and integrated with other aspects of their organization's decision-making process. They will need, in short, a decision-support system for conservation.

Introducing NatureServe Vista

For the past two years NatureServe, a non-profit conservation group that brings together science and information technology to enable conservation action (www.natureserve.org), has led a cross-disciplinary team of scientists, conservation planners, economists, GIS specialists, and software engineers to develop a decision-support system for land use and conservation planning. The project's goal is to help planners understand local ecosystems, identify high-priority lands and waters, and evaluate competing land use plans.

The result of this effort is Vista, a GIS decision-support system, built on Microsoft's C# .NET technology as an extension to ESRI's ArcMap 9.0 with Spatial Analyst. The system is supported by a network of experts to assist in applying the system to real-world land use and conservation challenges. It is currently in beta and scheduled for release in late 2004.



***The NatureServe Vista Extension**: Users access Vista data and functionality within ArcView 9.0 from either the NatureServe Vista toolbar or the "table of contents" tab.*

By building GIS mapping technology and scenario evaluation onto a solid foundation of conservation biology, Vista integrates complex biological information (e.g., the distribution and viability/integrity of sensitive habitats and threatened species, as well as their compatibility with relevant land-use), and policy (ownership, management practices, zoning and protection mechanisms). “Our goal is to create a high-quality GIS application that becomes the go-to product for conservation planning,” says Larry Sugarbaker, NatureServe’s Chief Information Officer. “We’ll continually improve the software in subsequent versions adding integration with other best-of-bread tools for conservation. The system’s functionality is fully documented and has been designed with ease-of-use as a top priority. Users will get customer support and expert assistance on biodiversity issues.”

Development team members include the University of California at Santa Barbara Biogeography Laboratory, the U.S. Geological Survey, the Wyoming Natural Diversity Database, the Florida Natural Areas Inventory, and ESRI. To ensure that the system meets the needs of the users, the Vista project is steered by an advisory panel of local and state officials and conservation leaders. The project was initiated in 2001 with generous lead support from the Doris Duke Charitable Foundation, and additional support from the Surdna Foundation, The Nature Conservancy, and the NASA REASoN program. The project methodology and GIS functions were piloted in Napa County with the Napa County Land Trust as client.

Case in Point: Napa County

At least 68 imperiled species, and several important natural communities, are found in Napa County, one of the highest figures for any county in America. Several species are endemic to the region. In the past decade, more and more hillsides have been converted from natural oak woodlands into vineyards. The grapevine monocultures are squeezing out habitat for native plants and animals, so species such as the California red-legged frog and the Napa milkvetch are becoming increasingly threatened.

The Land Trust of Napa County works to conserve the county’s natural diversity, scenic open space, and agricultural vitality. The land trust owns about 2500 acres itself, and has helped conserve another 30,000 acres through conservation easements and other means. John Hoffnagle, the trust’s Executive Director, points out that, like most of the 1,200 local land trusts in the United States, his organization has operated on a mostly reactive basis—protecting land as opportunities arise, such as through donations from conservation-minded landowners. “Land trusts are becoming more sophisticated and pro-active,” says Hoffnagley. “You’ve got to have a plan. There’s a natural marriage between NatureServe’s decision support system and what land trusts are trying to accomplish. It helps us focus on what we need to preserve.”

Assembling a Conservation Planning Database

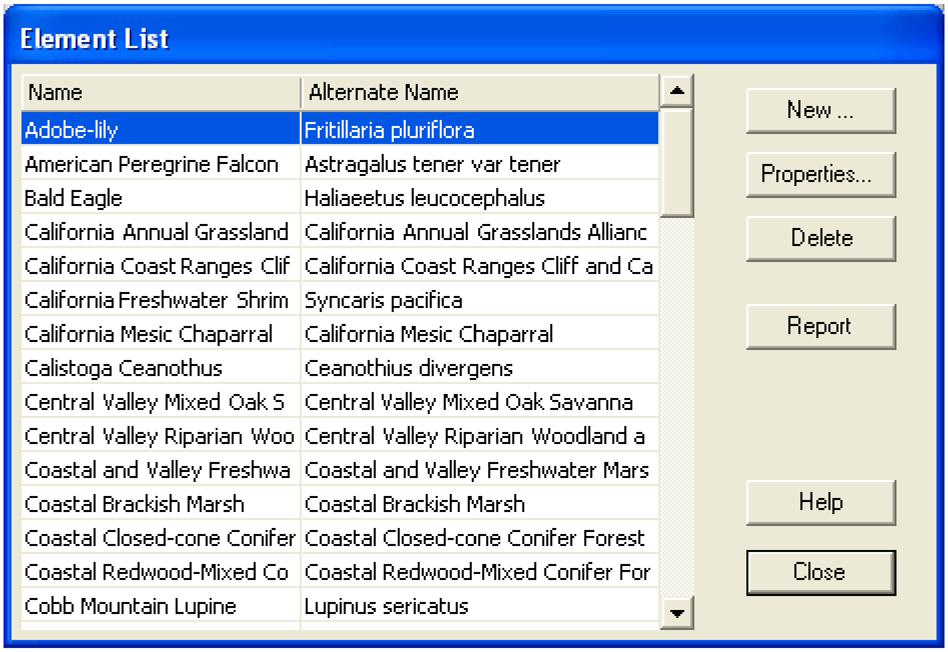
Building a decision support system for conservation combines three disciplines: conservation biology to assess and calculate biodiversity values across the landscape, local planning to understand and represent threats to biodiversity and, finally, software engineering to develop a standardized data model and generalize a set of processes into working software functions. The system provides tools to capture knowledge and expertise of biodiversity experts into a single conservation planning database, and then deliver that database along with a set of exploratory and planning tools to planners.

The cornerstone of the Vista data model is the set of elements to be conserved (typically species, communities, and ecological systems) along with the data layers that depict their local distribution. Local conservation projects usually begin with a team of local experts analyzing the biodiversity of the planning area to produce a list of conservation elements that effectively represent that biodiversity. Working with other local, regional, national and sometimes world-wide experts, the team then assembles the best available data on those elements and their distribution. This task includes acquiring, formatting, and assessing the quality of the needed data from a wide variety of data sources.

Element Information

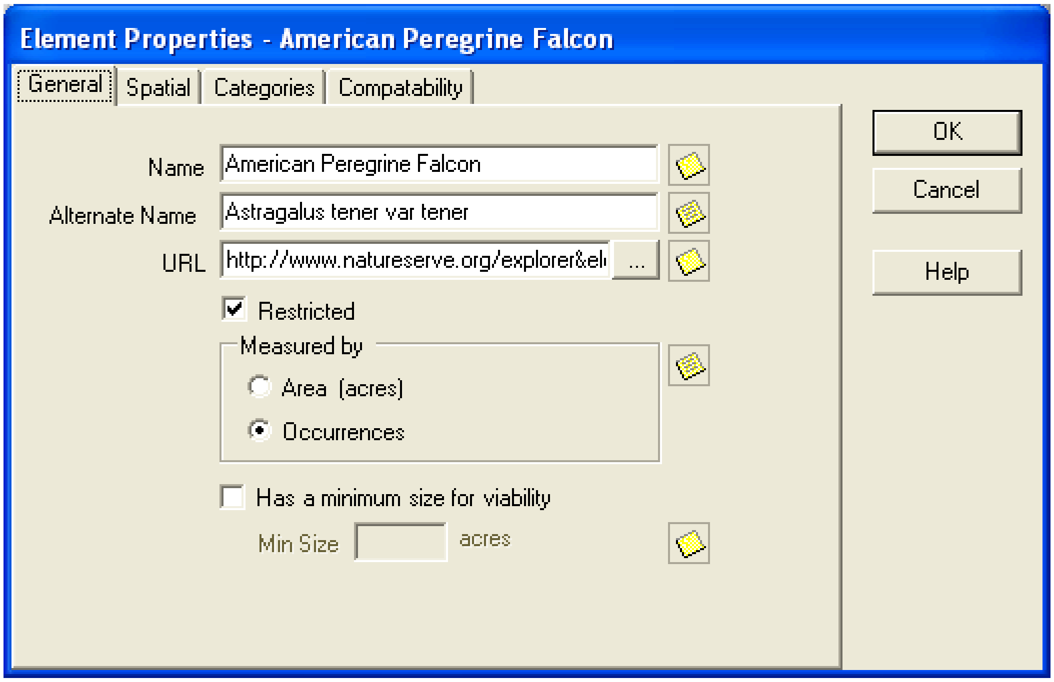
In Napa County, NatureServe identified conservation elements using two scales—a "coarse filter" and a "fine filter." The coarse filter identified representative ecosystems comprising most of the area's biodiversity, such as Napa's coastal redwood forests, mixed oak savannas, and coastal salt marsh, described according to a national classification of ecological systems developed by NatureServe *(see http://www.natureserve.org/publications/usEcologicalsystems.jsp)*. The fine filter identified the rare plants, animals, and natural communities, such as specific rare wetland or forest types, missed by the coarse filter. For Napa, documented locations of imperiled plant and animal species came from the California Natural Diversity Database and the California Native Plant Society.

Vista allows users to manage elements using the element list (shown here) or the Vista table of contents (next to the Display and Source default ArcMap table of contents).



Lists: *All database objects such as elements, category systems, weighting systems, etc are managed by a "list" user interface or by the entries in the Vista "table of contents"*

Vista's data model for elements captures the basic information about each element including its name, alternate (or scientific) name, URL at which a complete description may be found, and unit of conservation. Elements may be conserved by area, as in the case of ecological systems, or by occurrences as in the case of bird nesting sites. The unit of area is a project-wide preference and includes both imperial and international units.



***Element Properties**: All element information required for Vista analysis is entered on this form. All input fields are verified for valid input.*

There are three components of spatial information required for elements:

Distribution

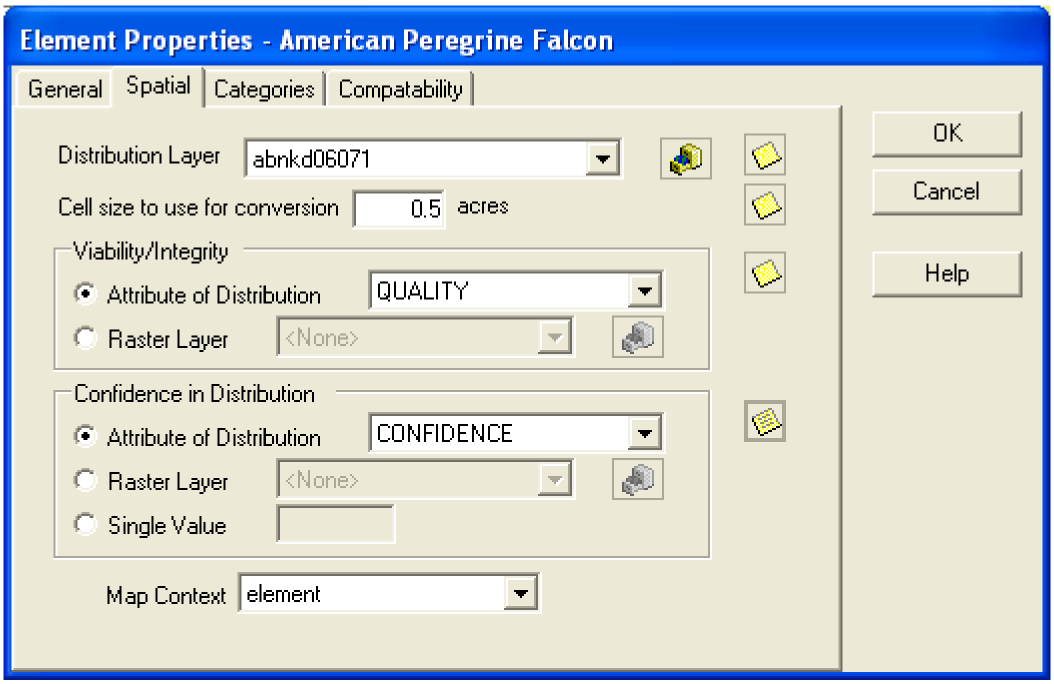
A shape or coverage file describing occurrences (polygons of presence) across the planning region. Distribution information may come from individual documented occurrences (e.g., for federally listed species), a computer model predicting occurrences based on habitat correlations, or remotely sensed data interpreted and classified (e.g., ecological systems).

Viability/Integrity

For each occurrence, a score of 0.0 to 1.0 describes the viability and/or integrity of that occurrence. Factors that go into this score include the occurrence size, condition, and landscape context. If occurrence-specific viability/integrity scores have not been documented (for instance, the element is an ecological system whose source is remotely sensed data), users may supply a raster layer describing relative landscape integrity. In Napa County for instance, a terrestrial landscape integrity layer was created based on the absence of roads, distance from pollution sources, distance from urban areas, etc. This single layer was then used to describe the integrity for all terrestrial ecological systems used in the analysis.

Confidence

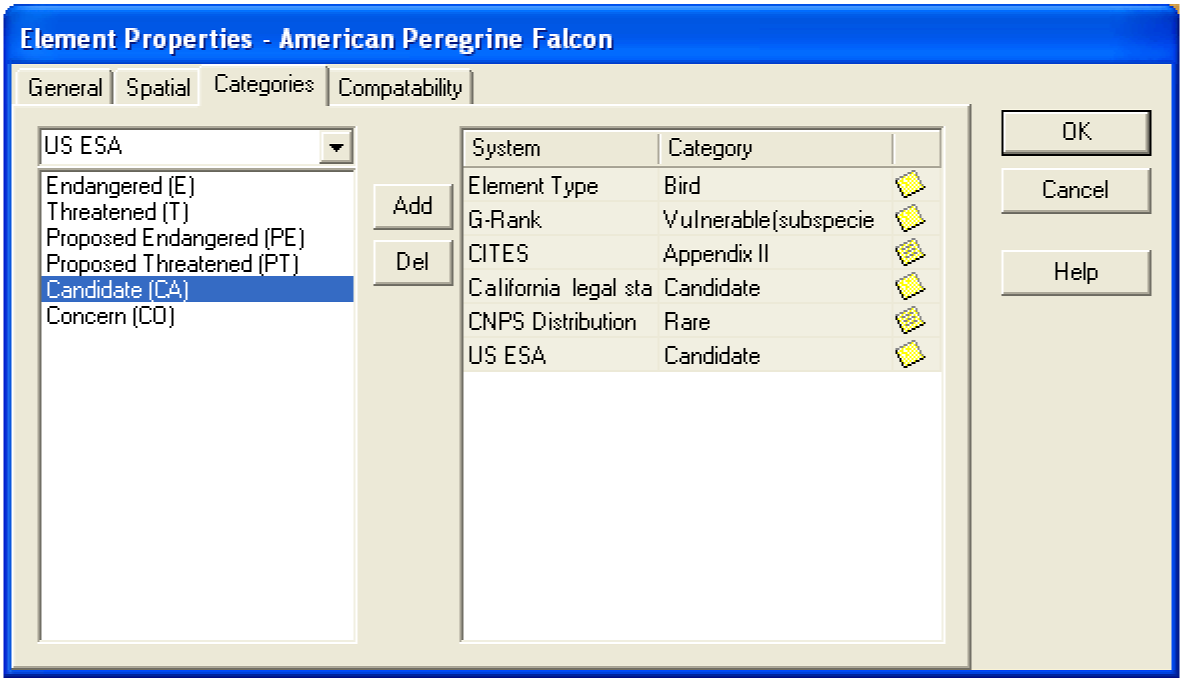
For each occurrence, a score of 0.0 to 1.0 describes the confidence or certainty that the occurrence location is accurate. Factors in confidence scoring include the age of the occurrence, whether it is a field-documented occurrence, and any spatial uncertainty. Documented occurrences from field studies containing these parameters can be translated into the confidence scale. Output from computer models predicting distribution is most often a raster of relative certainty. Vista will accept these rasters once translated in the confidence scale. If neither occurrence-specific nor a confidence raster are available for an element distribution, which is often the case, a single value for confidence can be provided, taking into account the element expert's knowledge of how the data was collected, its age, etc.



Element Spatial Properties: *Element distribution, viability/integrity, and confidence are entered in this tab of the element properties form.*

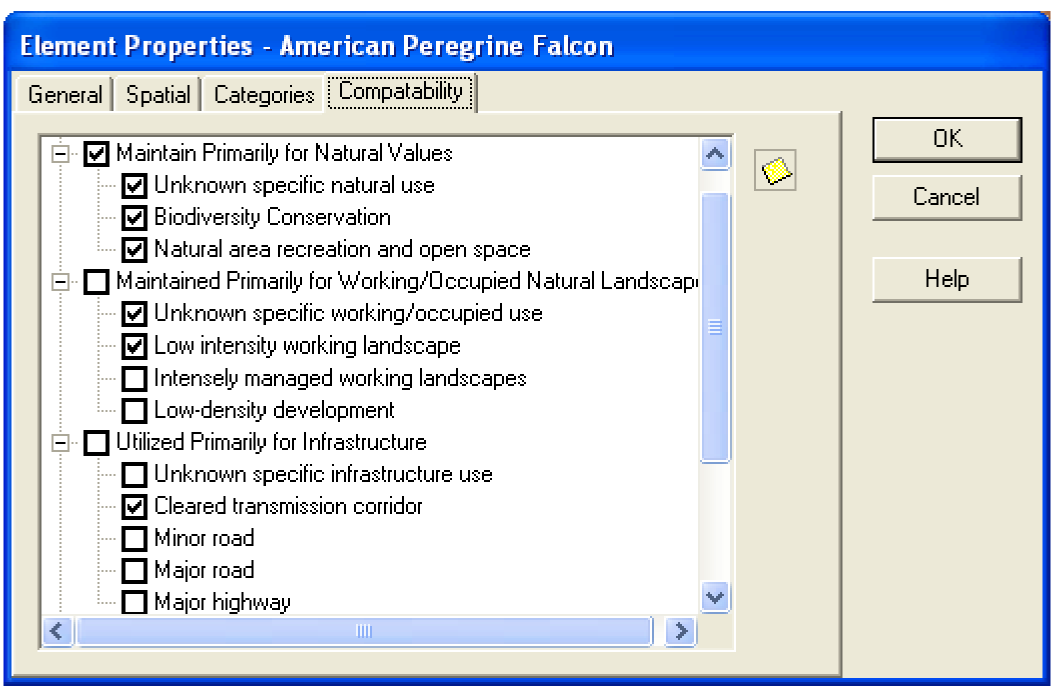
The small note button next to several fields provide access to a notes window where users can document decisions, such as the justification of a single value for confidence. These notes can then be optionally included in reports.

Vista allows users to categorize elements according to any number of category systems. The system ships with pre-defined category systems such as that defined by the U.S. Endangered Species Act and NatureServe's global conservation status system. Users can define their own category systems based on local considerations such as economic or historical value.



***Element Categories**: Users can categorize elements by any of the pre-defined category systems (shown in the dropdown list where "US ESA" is currently selected). Users can add their own category systems and categorize elements according to local concerns.*

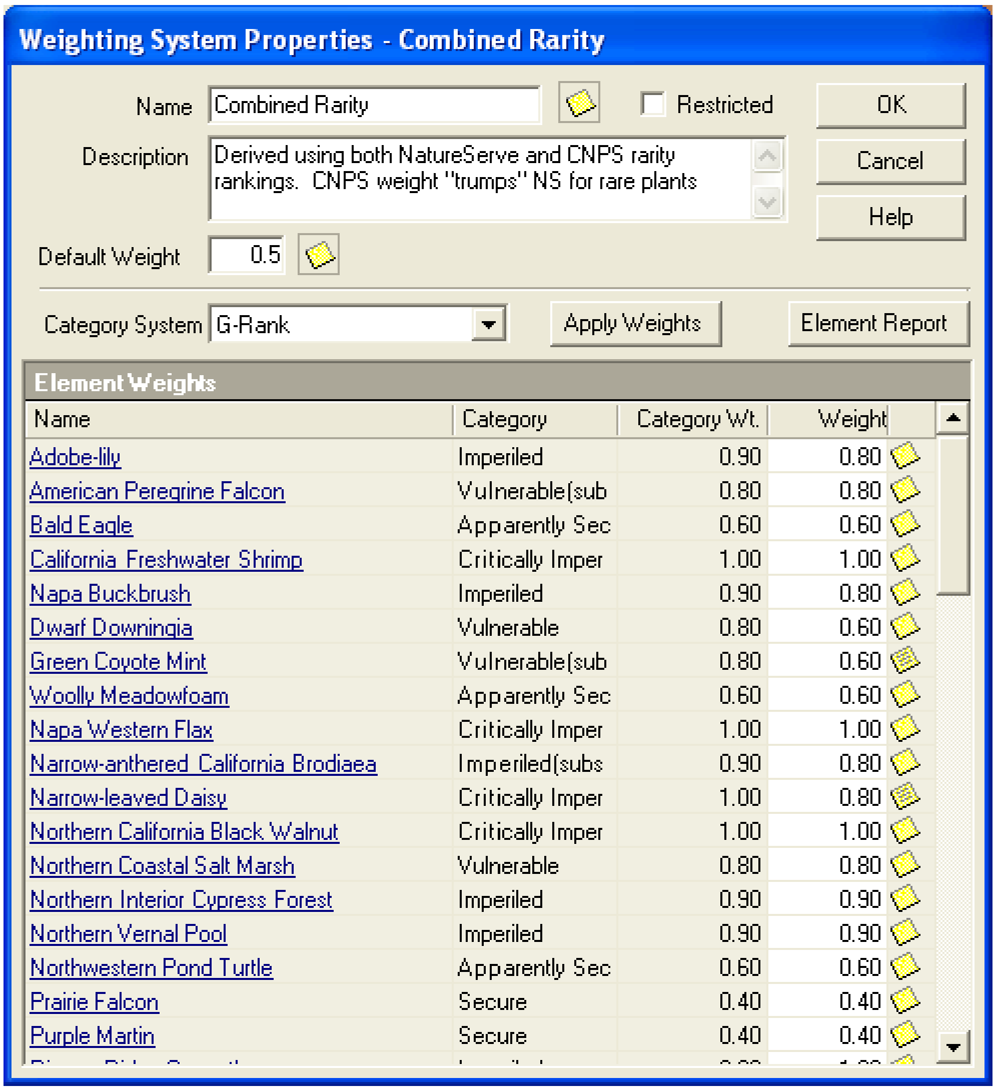
Finally, recognizing that not all elements of biodiversity respond identically to human activity, the element expert can also define the compatibility of the element with various land uses or land management practices. This information will be used in the evaluation of planning scenarios.



***Element Compatibility**: Each element's compatibility with the relevant land-uses and land management practices is described here.*

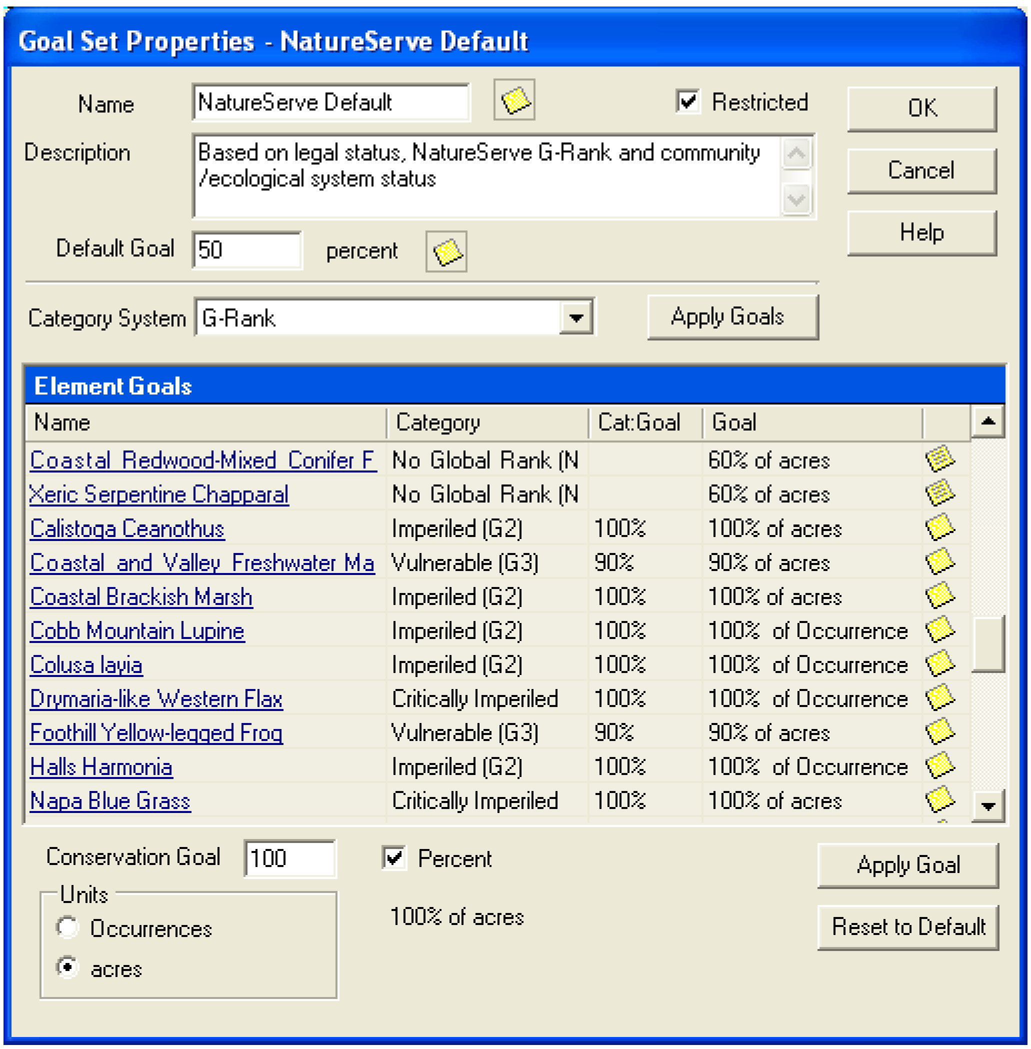
The list of elements to be conserved need not be limited to those identified by scientists as "at risk". On the contrary, elements contributing economic, character, or historical value to local communities may also be entered into the database, along with their distribution across the planning region.

Since not all elements are equal from a conservation perspective, weighting systems can be described that rank elements on a scale 0.0 to 1.0. A weighting system can be based on an established value system, such as the NatureServe global conservation status system that ranks elements according to their degree of global imperilment. Other weighting systems can be described which reflect the value system of various constituents, such as an element's value to the local economy, contribution to local character, or historical integrity.



***Element Weighting Systems**: Weighting systems can be based on defaults as defined by a category system and then customized by directly editing the weight. Each weight can be documented using the notes documention feature.*

Goals are established on an element-by-element basis and then saved as a "goal set." Category-specific goals can be established for a particular category system (e.g., 100% of all U.S. ESA threatened elements) and then applied to the elements within that category. Users can then make adjustments as need be. Like weighting systems, goal sets reflect a value system such as legal protection or economic value. By setting quantitative conservation goals, the user establishes a baseline against which both the existing land use status and scenarios for future land use can be compared, and progress tracked over time. Scenarios and scenario evaluations are covered later in this discussion.

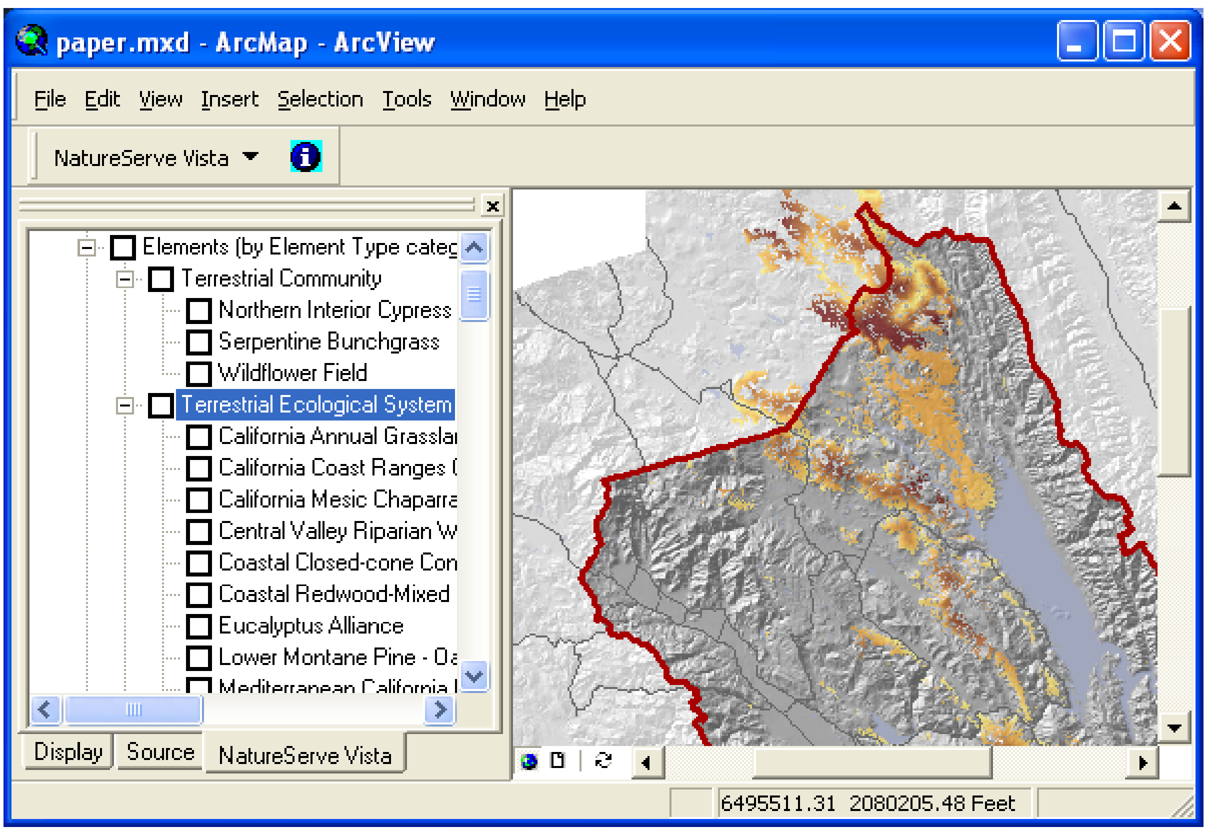


***Element Goal Sets**: Like weighting systems, goal sets can be based on defaults as defined by a category system and then customized by directly editing the goals. Clicking on an element name opens that element report which can aid in setting goals.*

Once the scientific support team has set up the project area database, identified the conservation elements, and generated the element data layers, default weighting systems and element conservation goals are added. The result is a customized conservation planning database that can be used directly in conservation planning or delivered to outside planners along with the software for their own use.

Element Conservation Value

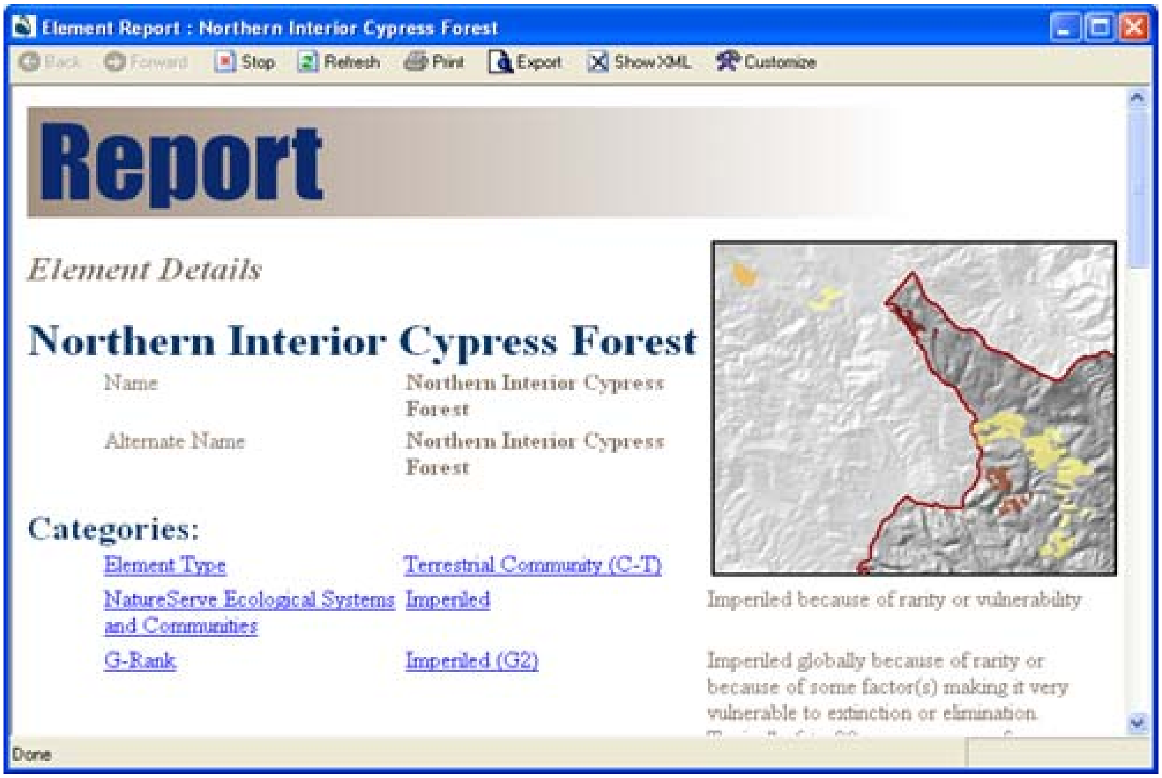
The local planner now has in hand a scientifically credible database depicting local biodiversity conditions. The first step might be to explore information on individual elements. The most basic analysis of a single element is to determine its conservation value across the planning area. Once distribution, viability/integrity and confidence information has been provided, the system creates a raster layer of conservation value for the element. Conservation value is defined as viability/integrity *x* confidence over the distribution of the element. Areas of highest conservation value for the element, then, are those with the highest viability/integrity and confidence scores and, conversely, those with the lowest conservation value are those with the lowest viability/integrity and confidence scores. The system automates the process of producing FGDC-compliant metadata that describes the data source, the data standards, and the confidence measure associated with each conservation element distribution layer.



Conservation value for Xeric Serpentine Chaparral in Napa County is shown here wherein darker orange represents higher conservation value.

Users might also generate reports on individual elements detailing the basic element attributes as described in the "Properties" dialog, as well as distribution statistics (number of occurrences and total area) and a map depicting conservation value.

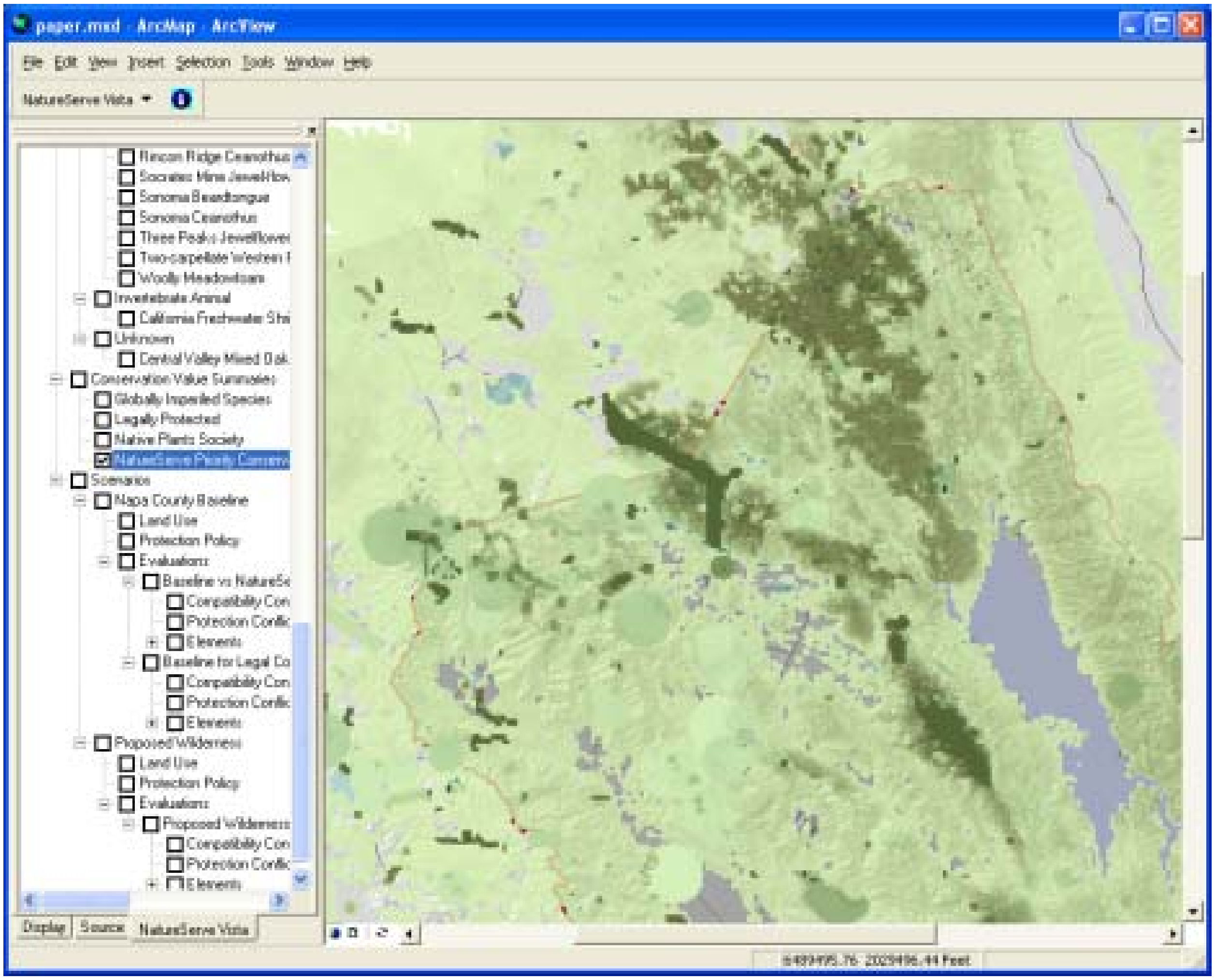
All Vista reports are presented in a web-browser interface. Reports are produced on-demand in XML and then transformed into HTML using XSLT stylesheets. Reports can be exported from the system to a file location, thus facilitating publication on a web site for public feedback.



Element Report*: The integrated browser presents reports in HTML and XML format. Documentation notes can be optionally included in the report.*

Conservation Value Summaries

The conservation value of individual elements can be combined to produce an overall summary of conservation value across the planning area. The summary aggregates all of the individual conservation value layers for elements (i.e., species, communities, and ecological systems), including their viability/integrity and confidence scores, and weights them according to their relative conservation importance as defined by a given weighting system. The result is a raster map of biodiversity hotspots highlighting the most important places for conservation in the region.

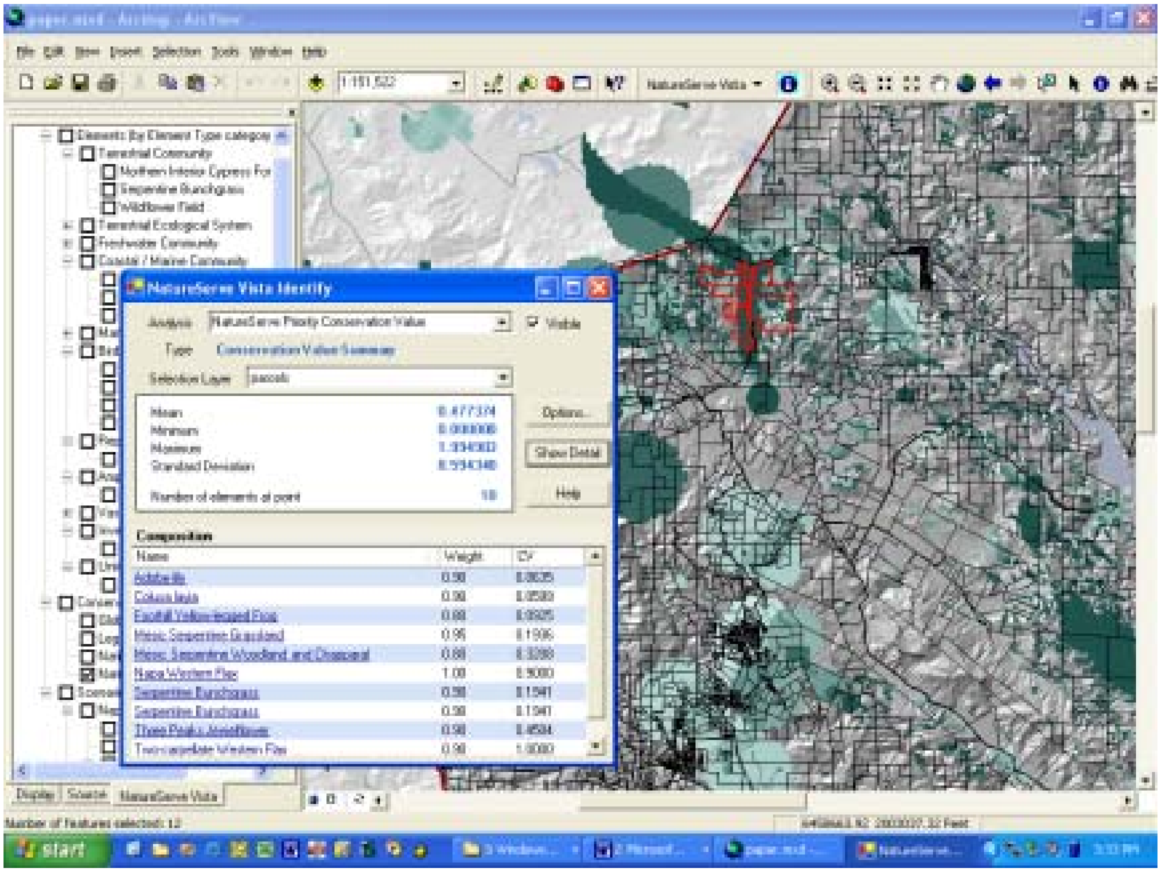


Conservation Value Summary*: A conservation value summary of all ranked species, ecological communities and systems in Napa County. The darker green represents areas of higher conservation value.*

Conservation value summaries can be customized in several ways. Filters can be defined which constrain the set of elements incorporated in the analysis (e.g., "Legally protected only"; "Legally protected or globally imperiled"). Users can also apply a custom weighting system in order to weight individual elements according to local priorities. The same set of elements can be aggregated according to different weighting systems to compare the priority conservation sites for different constituent groups. Finally, the analysis itself can be customized to understand element richness (unweighted elements without confidence or viability/integrity attributes), or concentrations of high viability/integrity or low confidence.

Drilling Down

Vista includes a specific tool to allow planners to understand the conservation value in selected analysis units. If the data supports such resolution, the user can utilize Vista's Identify tool to select a conservation value summary and, optionally, an analysis unit layer such as parcels to get the mean, minimum and maximum conservation value, as well as a list of the elements with occurrences in the selected analysis units, along with their weights and contributing conservation values.



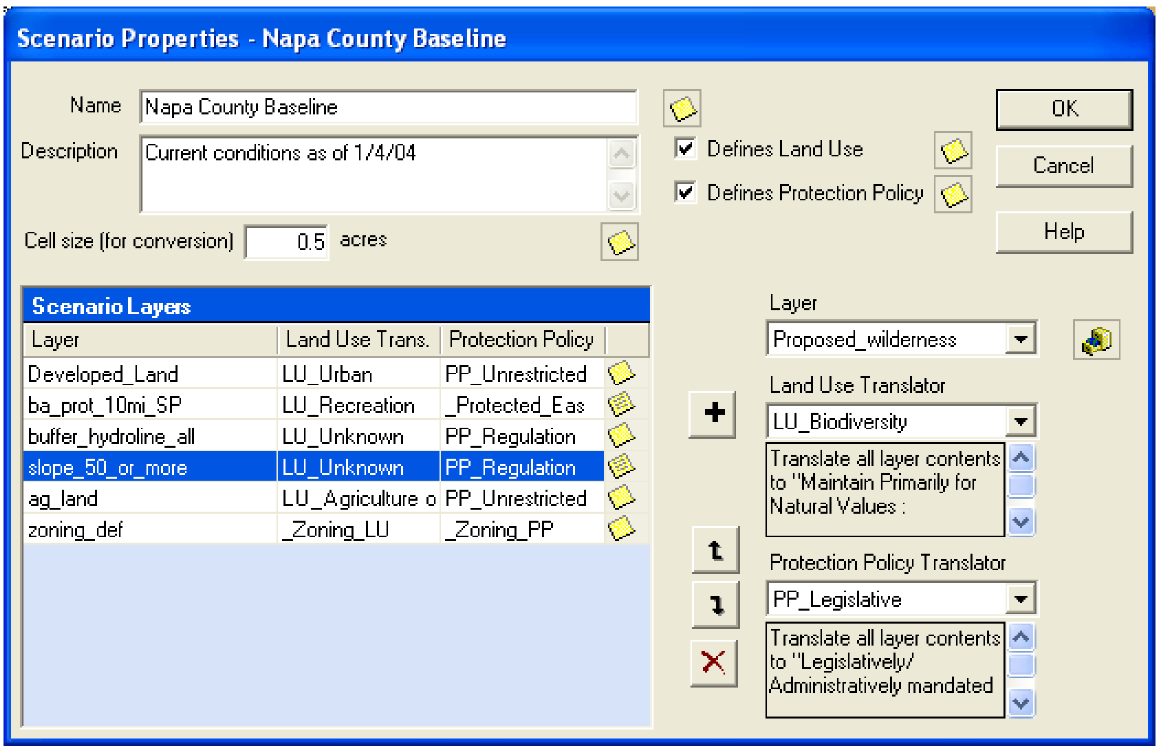
Vista Identify*: Conservation value statistics on the selected parcels (shown in red, difficult to see in grayscale) include minimum, maximum and mean conservation value. The list of contributing biodiversity element, their weights and the mean conservation value for the selection is available by clicking "Show Detail."*

With the conservation value summary in hand, the planner is on the way to setting conservation priorities. He or she now understands which parcels are most important for conservation, and which may be more suitable for development, such as housing or vineyards. The planner can now set conservation goals, explore the compatibility of the current land use status with these goals, and identify the gaps in protection.

Up to this point, the analysis had been purely about ecological considerations. But to judge conservation compatibility, the system must integrate biodiversity value with socioeconomic factors, such as current land use, current conservation status, ownership, and land costs. For the Napa County pilot project, data about these topics were acquired from multiple sources including the Napa County planning department, the Green Info Network, the USGS California GAP program, and the Bureau of Land Management.

Importing Land-Use and Protection Scenarios

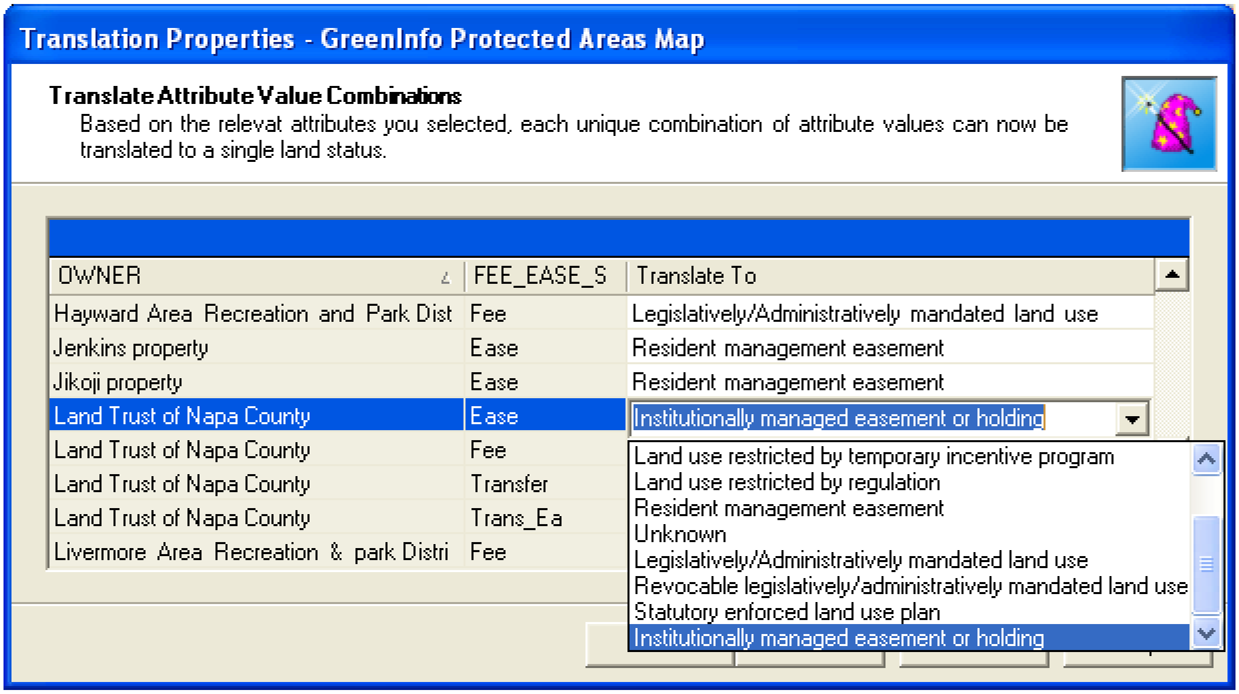
One of the most powerful features of Vista is its ability to compare various land use and conservation scenarios—in other words, alternate plans that identify which places to conserve and which places to designate for housing, roads, or other development. The software allows users to import scenarios obtained from a variety of independent sources, automating their translation into a common land use/management practice standard that can be compared against element distributions.



Importing a Scenario: *The scenario import feature takes layers in their native format, without manipulation, and translates planning unit attributes to lists of common land use/land management practices and common protection policies. The resulting land-use/management practice and protection policy rasters are then compared to element distributions for goal evaluation.*

Scenarios are composed of individual layers from multiple agencies (e.g., U.S. Forest Service) or representing different policies (e.g., stream setbacks). Protected areas are translated according to both the land use permitted (e.g., biodiversity reserve, recreational open space, low-intensity agriculture.) and the type of policy providing protection (e.g., voluntary, easement, legislated). Layers are ordered according to the precedence of their application (e.g., zoning is usually the last policy to define allowable land uses, so it typically appears at the bottom of the list).

A translation wizard allows users to crosswalk the attributes describing land use in the input layers to the list of land use/management practice used by Vista in order to determine element compatibility. First, the user selects the attributes of the input layer that are relevant to land use/management practice. After the system assembles a list of unique permutations of values for those attributes, the user selects the land use/management practice that correspond to those values. Translations are saved in the Vista database so that new versions of land use/management practice layers (e.g., an updated layer from the Bureau of Land Management describing new land use policies) can be directly incorporated into a scenario. The same process is used to translate protection policies. A translation of "GreenInfo Protected Areas" to protection policy is shown below.



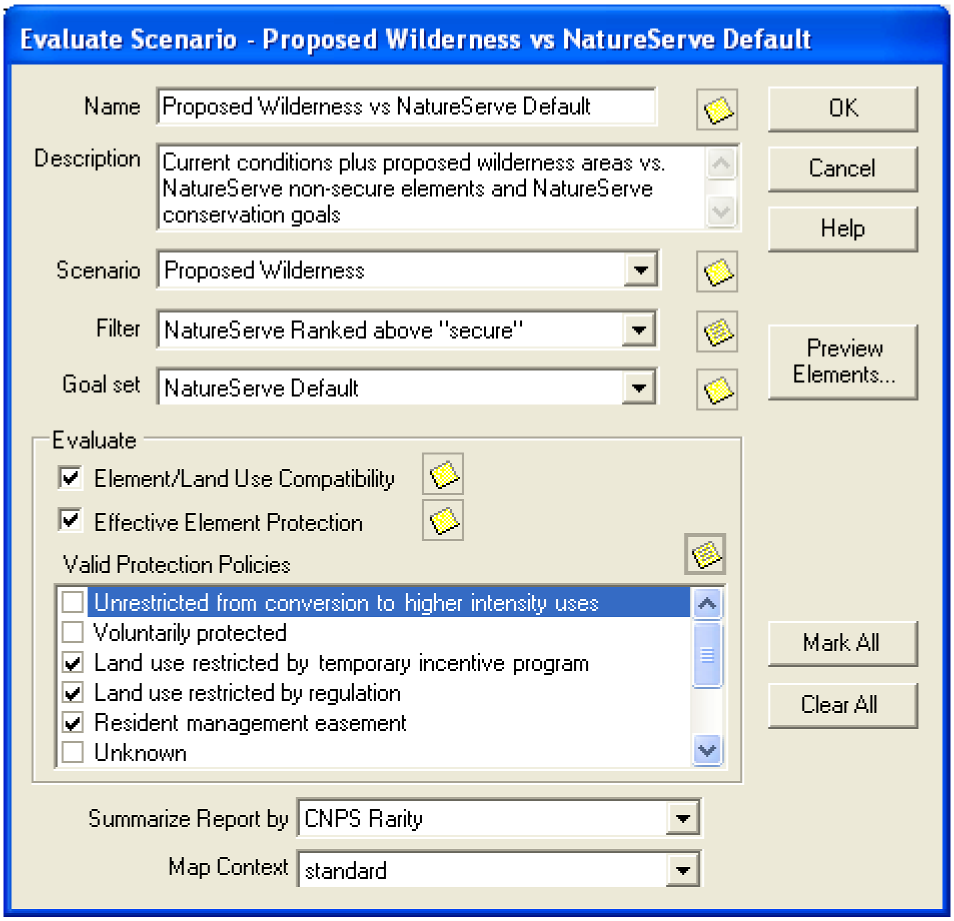
Translating Protection Policy*: Shown here, a user is translating protection policy from a"GreenInfo Protected Areas" layer. The selected relevant attributes (chosen on a previous page of the wizard) were "OWNER" and "FEE_EASE_S". All permutations of values in those two columns are shown in this list, and the user is translating those combinations to the corresponding protection policy.*

Using the input layers, their translations, and order of precedence, the system creates two maps to describe the planning scenario: a final land use/management practice raster and a protection policy raster. These are then compared to individual element distributions to determine the degree to which the scenario meets compatibility and/or protection goals for the elements.

Evaluating Land Use and Protection Scenarios

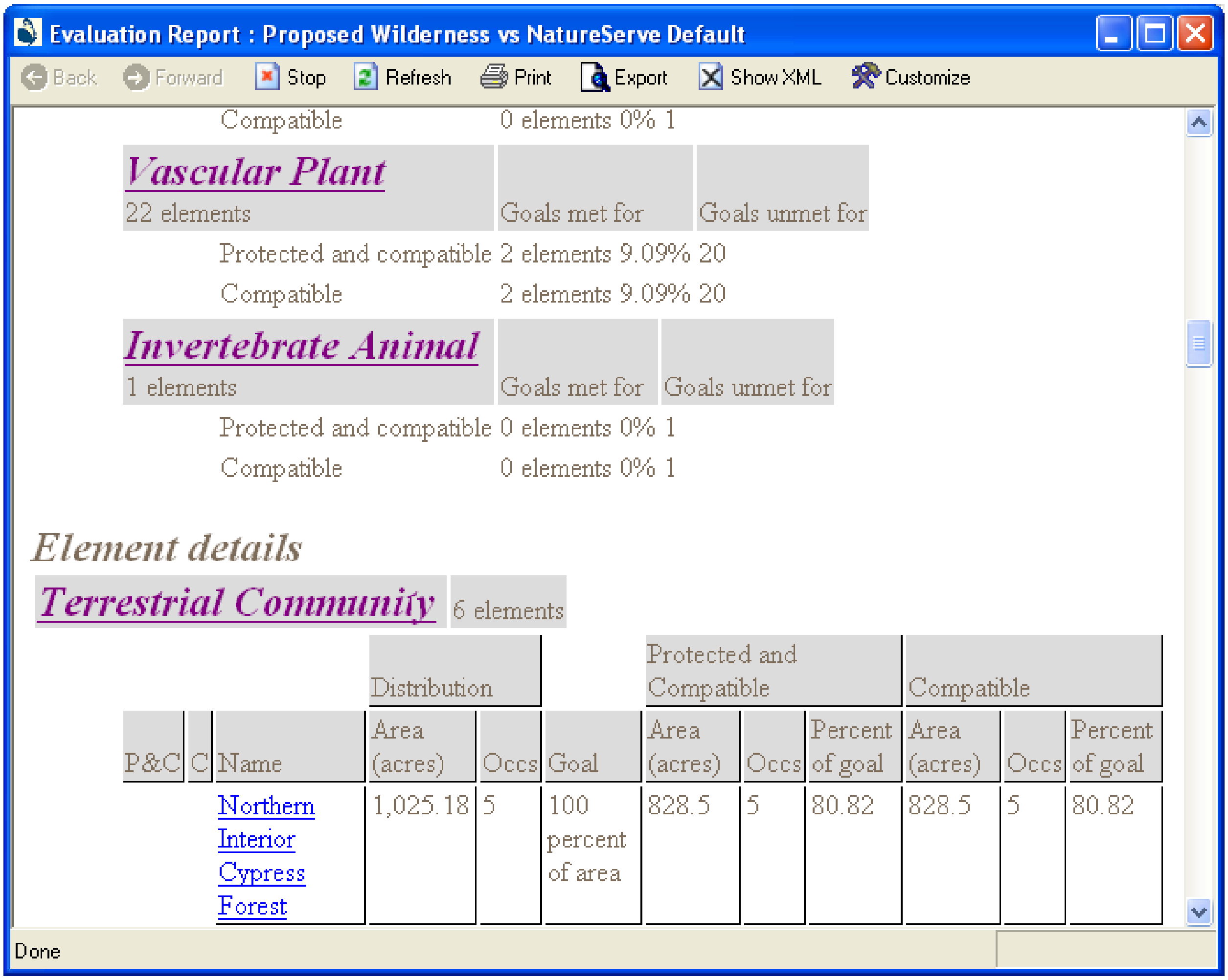
Vista can assess the performance of an input scenario, whether it describes current conditions or some possible future conditions, with respect to a given set of elements and a set of conservation goals. Through this analysis, the planner now begins to see where current land use is incompatible with conservation goals, and where potential land use conflicts may be on the horizon.

To evaluate a scenario, users select the scenario, the filter (defining the set of elements to be evaluated), and a goal set. If protection goals are being evaluated, the user must also select the set of protection policies considered to offer valid protection. This decision, like the element filter and goal set, may be altered to create multiple evaluations of the same scenario to be compared.



Creating a Scenario Evaluation *To evaluate a scenario, users select the scenario, the elements to be evaluated (via the filter selection), and the compatibility or protection goals against which the scenario will be evaluated. When evaluating protection policy, users can decide which protection policies will be considered valid (i.e.,reliable) for this evaluation. Finally, reported results can be summarized based on any category system.*

The result of this analysis is two maps and a report. The report summarizes, in total and then by category, the performance of the scenario in terms of the number and percentage of elements that met conservation goals. The report then provides a detailed comparison of individual elements against the scenario: their original distribution, and the amount/percentage that was retained in compatibility and the compatible amount that was also protected.



Evaluation Report : Proposed Wilderness vs NatureServe Default

Back Forward Stop Refresh Print Export Show XML Customize

Compatible	0 elements	0%	1

Vascular Plant 22 elements	Goals met for		Goals unmet for
Protected and compatible	2 elements	9.09%	20
Compatible	2 elements	9.09%	20

Invertebrate Animal 1 elements	Goals met for		Goals unmet for
Protected and compatible	0 elements	0%	1
Compatible	0 elements	0%	1

Element details

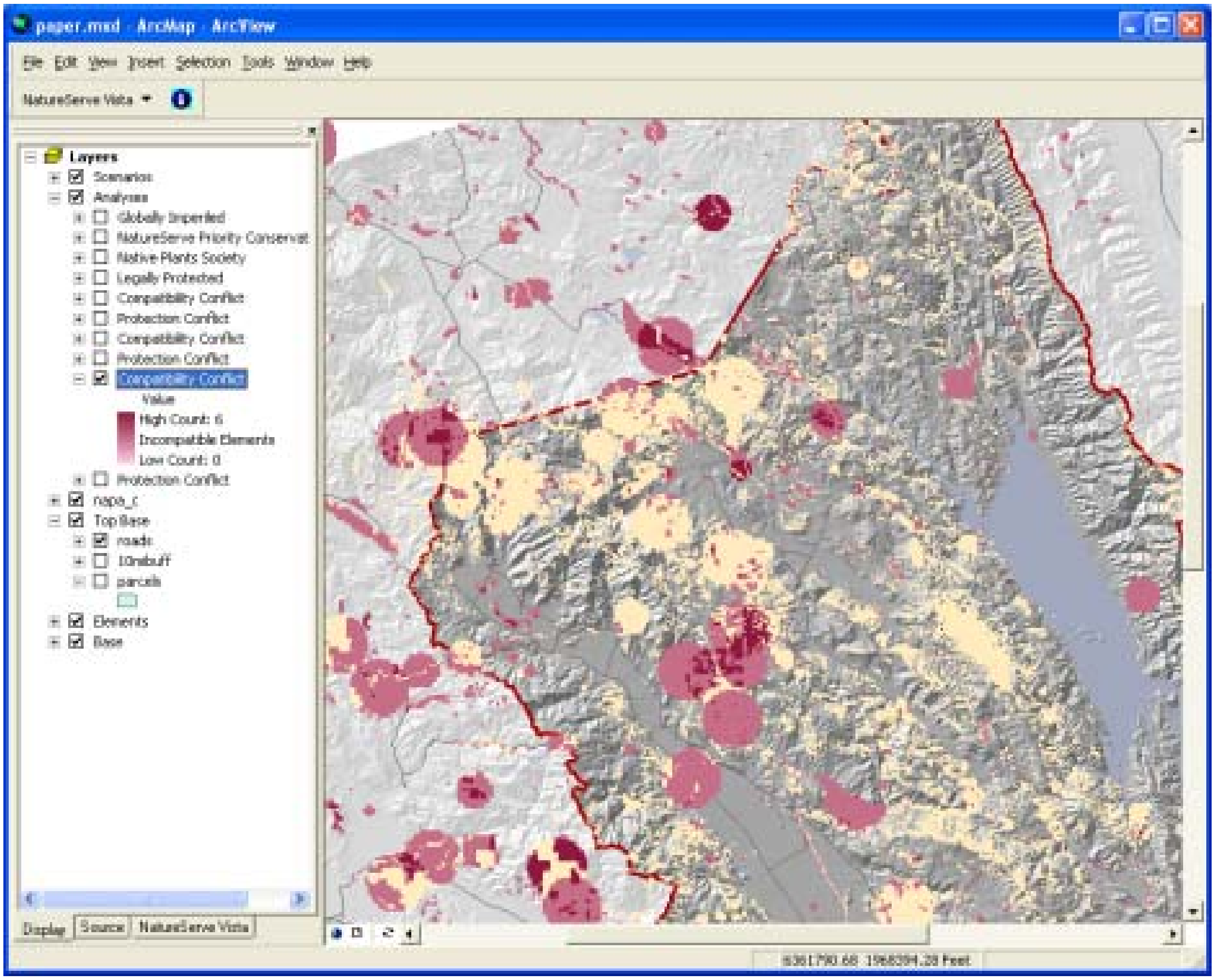
Terrestrial Community
6 elements

			Distribution			Protected and Compatible			Compatible		
P&C	C	Name	Area (acres)	Occs	Goal	Area (acres)	Occs	Percent of goal	Area (acres)	Occs	Percent of goal
		Northern Interior Cypress Forest	1,025.18	5	100 percent of area	828.5	5	80.82	828.5	5	80.82

Done

Scenario Evaluation Report: *Summarized by Element Type, the report shows how many elements did or did not meet their goals as established in the evaluation properties. Then each category is broken down into the performance of the scenario against individual elements and their goals. In this example, the scenario met approximately 80% of the 100% goal for the Northern Interior Cypress Forest. All compatible areas of distribution were also protected.*

Two maps help the user understand where opportunities to improve performance against goals exist. The first shows “hotspots of incompatibility”, allowing the user to identify those areas where elements with unmet goals due to incompatibility of land use are concentrated.



Visualizing a Scenario Evaluation: Compatibility Conflicts *In the map above, tan represents occurrences of elements with met goals or compatible land use. Increasingly dark red, on the other hand, represents areas containing an increasing number of elements with unmet goals and a compatibility conflict with the scenario's defined land use for that area.*

A similar map of protection policy conflict shows the areas where elements are compatible, but insufficiently protected to meet the goals. Finally, a set of separate maps is generated, one per element included in the evaluation, which allows the user to visually distinguish areas of incompatibility, compatibility without protection, and compatibility with protection for a single element.

Reaching Planning Decisions; Repeating the Process as Conditions Change

The ultimate purpose of any conservation planning effort is to build consensus and make sound decisions that conserve biodiversity and support the community's goals. Vista makes this possible through its solid scientific foundation combined with a dynamic approach that empowers the planner to explore different options.

Throughout the process, the user has the power to choose the conservation goals for each scenario, the elements to conserve, and how to weight them. The user can also choose which local planning policies (such as Napa's streamside buffer ordinance) should be enforced. Changing any of these assumptions could result in a different set of parcels being identified as priorities. Although the Napa County pilot project focused on biodiversity, the software allows users to define and analyze conservation elements of various types, not just species and ecological communities or systems. The elements may be farmland, open space, scenic vistas, historic sites, and so on, each of which could be weighted the same as elements of biodiversity.

Once the various conservation scenarios have been compared, the planner can produce the final maps and reports, and use these tools to aid the decision-making process. Because scenarios and conservation elements can be changed by the planner, this process can be repeated as often as needed to test alternate land use scenarios, or re-run scenarios when new data become available. Vista will save and document the results, an important feature for defending regulatory decisions.

Putting the Results to Use

Decision-support systems have some impressive potential benefits for the local user and for conservation. Planning can be done more efficiently; tax dollars can be spent more wisely; costly legal conflicts can be averted. Using Vista, the community can develop a plan to conserve what it values most, balancing diverse land uses and priorities, such as natural habitats, farmland, and historic preservation.

Back in Napa County, John Hoffnagle is optimistic that his county can safeguard its scenic landscape, its rare species, and its agricultural heritage, the vineyards. Although he is excited about the potential of Vista, Hoffnagle also emphasizes that "successful conservation will never be just about running a software program. That human interaction will always be needed with planners, conservation biologists, local officials, and landowners."

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