REGIONAL ADVANCE MITIGATION PLANNING: A PILOT STUDY INTEGRATING MULTI-AGENCY MITIGATION NEEDS AND ACTIONS WITHIN A COMPREHENSIVE ECOLOGICAL FRAMEWORK

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ABSTRACT

Compensatory mitigation required of infrastructure agencies to fulfill regulatory requirements is often implemented in the latter stages of project construction. It also tends to be focused on project specific impacts that are localized around the area of impact. This single project approach to addressing unavoidable impacts to natural resources is non-systematic and piecemeal. The late timing of mitigation can lead to both greater expense for and reduced ecological integrity of lands dedicated to impact offsets. In order to increase resource enhancement opportunities, funding source efficiency, and ecological function and sustainability, the concept of a Regional Advance Mitigation Planning (RAMP) effort was launched in California. Two infrastructure action agencies (California Departments of Transportation and Water Resources) worked with The Nature Conservancy, UC Davis, EDAW/AECOM, and the Resources Legacy Fund Foundation to bring together state and federal regulatory agencies to initiate a RAMP framework and identify likely mitigation requirements for a set of infrastructure projects within our pilot study area. Project "footprints" were estimated and their overlap with regulated ecological features was calculated. Using typical compensatory mitigation ratios, total regional mitigation needs were projected. Further, a framework was developed for identifying sites that could meet these ecological requirements with the lowest costs and the greatest contribution to regional and statewide conservation priorities, such as larger ecological reserves and greater landscape connectivity. This project is unique in its methodology. It combines mitigation requirements from transportation and water delivery, and flood management projects within the study region and identifies suitable mitigation sites that align with regional conservation objectives. When the environmental obligations from multiple agencies are integrated, planners can leverage program resources towards more significant habitat conservation at ecologically relevant scales across regions. This approach has multiple benefits to the resources of the State with greater fiscal efficiencies. The model developed here, if successful, is intended to be used throughout the state of California in the future.

INTRODUCTION

Habitat conversion by humans is an ongoing, large-scale process that is responsible for the population decline of many species and degradation of ecological communities (Wilson 1992; Foley et al. 2005)). Much of this conversion is driven by the development of infrastructure to meet human needs, such as housing, transportation, and resource extraction (Hardner and Rice 2002). The cumulative extent and effects of these activities is expected to increase in the foreseeable future as a result of human population growth and expanding economic investment (World Bank 2007). If biodiversity and ecosystem services are to be maintained, policy mechanisms are necessary to address these impacts.

One increasingly adopted measure in this regard is compensatory mitigation, or biodiversity offset (Kiesecker et al. 2009a; Kiesecker et al. 2009b). While it is widely acknowledged that ecological impacts should first be avoided, minimized, or restored at the location of the impact (CEQ 2000), many times there are unavoidable biodiversity losses that cannot be addressed in this manner if a particular infrastructure project is to be implemented. In this case, preservation or restoration of equivalent (or "like for like") ecological components, preferably spatially proximate, can be required. An example is the "no net loss" policy for wetland mitigation that was enacted at the national level for the United States in 1990 (Bendor 2009).

One set of organizations that routinely use compensatory mitigation actions to help offset negative effects to ecosystems is public infrastructure agencies. These agencies use public funds to construct and maintain roads, water delivery systems, flood control structures, and other infrastructure components. In so doing, there are often impacts to existing ecosystems (Forman 2000) which require some form of compensatory mitigation. These impacts can range from small, temporary disturbances associated with certain road repair projects to habitat loss on the scale of thousands of hectares for large water delivery projects or major highway construction. Because there are often many assorted infrastructure projects within a given region on an annual basis, there is the potential for a substantial cumulative effect on species and habitats found within that region, and hence the possible need for substantial mitigation activity. There have been some recent attempts to integrate these activities within a regional, comprehensive framework (e.g. SAFETEA-LU; U.S. Congress 2005).

Compensatory mitigation generally occurs on a piecemeal, project-by-project basis (Thorne et al. 2009a) which has several drawbacks. One outcome is that as a result of the reduced mitigation requirements of any one project, parcels used to fulfill mitigation needs are necessarily smaller in area and thus potentially less valuable from an ecological perspective. This is especially true for those parcels that are isolated from other ecologically relevant natural or conservation lands (habitat fragmentation). Thus, these parcels do not necessarily contribute to regional conservation goals, or a collectively-defined "greenprint". We define greenprint as the compilation of multiple regional landuse analyses created by regional conservation organizations or governments that identify habitat conservation areas of any type specified for protection. Smaller parcels also generally cost more on a per acre basis than do larger parcels, thereby increasing the overall financial cost of the mitigation. Also driving up cost is the timing of the mitigation actions; these usually occur in the latter stages of the infrastructure project. This timing incurs greater costs both because of the generally upward trend in real estate prices, the time-value of money, and the potential delays associated with acquisition and regulatory agency approval of the compensatory measures undertaken (American Association of State and Highway Transportation Officials 2003).

A regional approach to compensatory mitigation planning can lead to an improved ecological outcome. If mitigation needs from multiple projects are pooled, larger, less fragmented parcels can be acquired, contributing both to ecological integrity and fiscal savings. Further, parcel acquisition can be focused on areas identified as conservation priorities, providing support from a broader array of stakeholders. Other time and cost savings can accrue from eliminating redundancy associated with regulatory processes if fewer but spatially larger parcels are acquired for project impact compensation.

Additional savings can be realized if the regional mitigation planning happens in the early stages of project delivery rather than the more usual latter stages. If regulatory approval is achieved through implementation of an effective planning process, parcels can be acquired before they increase in price and costly delays can be avoided in infrastructure construction. The long planning horizons associated with infrastructure agencies further uniquely position them to contribute to the implementation of a long term regional greenprint.

This study reports an ongoing process in California, USA, that brings together two public infrastructure agencies – the California Departments of Transportation (Caltrans) and Water Resources (DWR) – with the regulatory agencies that oversee their mitigation requirements – the United States Fish and Wildlife Service (USFWS), California Department of Fish and Game (DFG), United States Environmental Protection Agency (EPA), National Marine Fisheries Service (NMFS), and United States Army Corps of Engineers (ACE). In addition The Nature Conservancy (TNC), University of California, Davis (UCD), Resources Legacy Fund Foundation (RLFF), and EDAW/AECOM (a consulting firm) are participating in a technical advisory capacity. This collaboration will produce a framework for bundling mitigation requirements of multiple projects at a large regional scale (1000's of square kilometers). The framework will include identified processes for upfront approval by the regulatory agencies, that will permit the mitigation planning process to occur earlier, or even in advance of, project implementation than is usually the case. The goal is to increase the positive ecological impact of offsite compensatory mitigation while reducing the overall cost of infrastructure project implementation.

In order to achieve this goal, a number of steps for integrating regional conservation plans with projected regional infrastructure impacts (Thorne 2009b) were undertaken as part of a pilot study designed to demonstrate and implement the overall framework in one region of California. First, planned infrastructure projects for Caltrans and DWR were identified within the region and their likely ecological impacts estimated. Second, typical mitigation requirements associated with the expected impacts were calculated. Next, a site-selection tool was used to identify parcels that could contribute to meeting the regional compensatory mitigation needs. Final steps include site specific analysis of several areas most likely to contribute significantly to meeting mitigation needs and comparison of the parcel selection analysis to an identified regional greenprint to merge mitigation actions with regional conservation goals. These final steps are scheduled to take place in the summer of 2009. This paper details the methods used in the above steps and draws some conclusions about the process of regional advance mitigation planning and its potential use in future conservation planning efforts.

STUDY AREA

The area chosen for analysis is a subregion of the Central Valley, California, located north of the city of Sacramento (Figure 1). It was selected both because of the presence of a number of species and communities that require mitigation and because there are a variety of infrastructure projects planned there by both of the participating agencies (Caltrans and DWR).

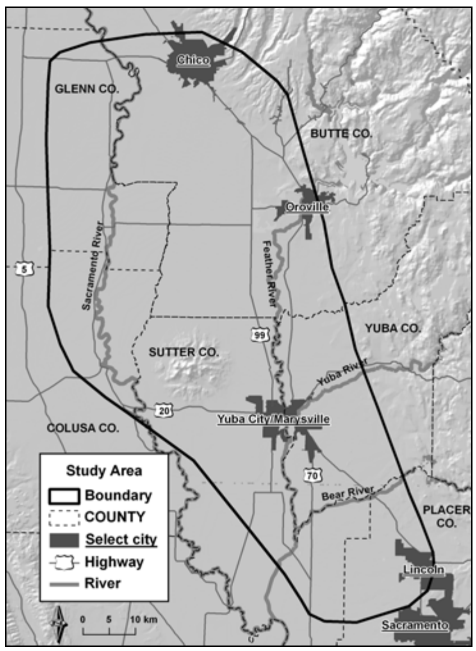

Figure 1. Regional advance mitigation planning area.

The Central Valley ecoregion is an area known for its historic biological richness and diversity (Ricketts et al. 1999). However, widespread conversion of natural ecosystems to largely agricultural (and increasingly urban) land cover has led to extensive fragmentation and ecological degradation. Further, important controlling ecological processes, notably fluvial processes such as flooding and meander dynamics, have been largely eliminated by historic flood levee construction. Currently the major native ecosystem patches in this region consist of riparian forest, valley oak woodland, blue oak woodland, freshwater emergent wetland, and grassland (some of which contain vernal pool complexes).

METHODS

The overall regional advance mitigation planning (RAMP) process engages in a number of topics, including policy and financing components. This paper however focuses on the technical aspects of identifying native habitat landscape parcels and/or parcels that would benefit specific species through restoration for potential use in this planning framework.

The first step in assessing regional mitigation needs for this study area was identification of the planned infrastructure projects. A database of planned Caltrans projects was obtained and rendered into a geographical information system (GIS) for spatial analysis. DWR project boundaries were estimated and digitized within a GIS.

Project impact assessment required estimation of the areal extent of the infrastructure projects. While the DWR project boundaries were already approximated, we needed to convert the linear Caltrans project data into polygonal data. We used a table of typical project-specific estimates (Thorne et al. 2009b), assembled by Caltrans agency personnel, to buffer the centerline of the roads dataset (Figure 2).

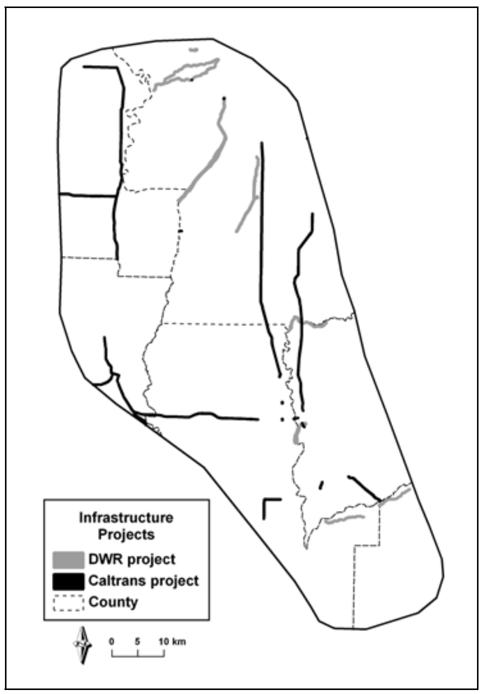

Figure 2. Caltrans and DWR project footprints.

We then overlaid these project footprints on a land cover dataset assembled from a number of sources (Nelson 1998; DWR 2005; Jones and Stokes 2005; SAIC 2007; Jones and Stokes 2008). From this overlay we obtained the summed estimated impact to general vegetation types by the infrastructure projects.

Project impacts to specific regulatory plant and animal species were estimated by identifying likely habitat for the selected species and overlaying the infrastructure footprints on this area. Habitat was defined as land cover types rated as “high” quality in the California Wildlife Habitat Relationships system (DFG 2005) and was within a 3 km radius of known occurrences of the species (DFG 2009). The project impacts were then assessed by summing the amount of habitat for each species that intersected the project footprints.

Mitigation requirements are often calculated by applying a ratio of affected area to area needed for either preservation or restoration (or both) “No net loss” policy, for example, generally is interpreted as requiring a 1.1:1 ratio (i.e. slightly more area required as compensatory mitigation than area impacted) for restoration activity. Preservation ratios however can vary widely. We consulted with regulatory agency personnel active in the study area to estimate the ratios usually required for preservation of existing lands as ecological offsets for impacts for each of the regulatory species. Total mitigation needs were calculated by applying the identified ratios to the total estimated project impacts.

Regulatory agencies generally require that compensatory mitigation activity take place in the vicinity of the impacts. Because the extent of this pilot project was larger than is typically permitted, it was necessary to spatially stratify the vegetation types and species-specific habitats. For most of these ecological components, watershed boundaries of the five large study area rivers (Sacramento, American, Yuba, Feather, and Bear Rivers) were used as the stratification units (Figure 3). Impacts to giant garter snake habitat were stratified by the low elevation basins delineated by the rivers (Natomas, Sutter, Colusa, and Butte Basins). Finally, vernal pool impacts were delineated into 11 “core areas” (defined by the USFWS). Thus project impacts to a regulatory species or vegetation type in one stratification unit must be mitigated for within that same unit. For modeling purposes, each stratified area for each ecological component is treated as a different species.

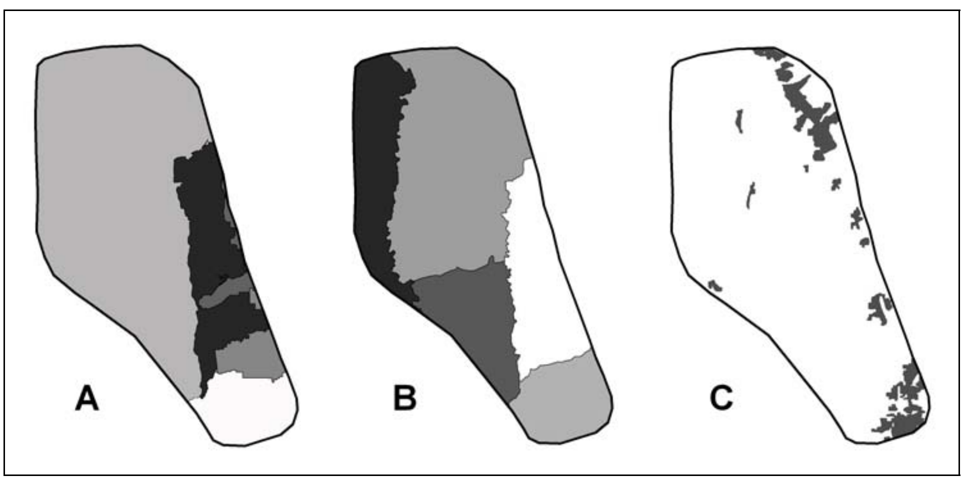

Figure 3. Spatial stratification of project impacts and required mitigation: A) major watersheds, B) basins (for giant garter snake), and C) vernal pool complexes.

Ownership parcel datasets for the six counties encompassed in the study area were combined into one dataset to be used as the units of analysis for this project. Each parcel was attributed for inclusion in an existing conservation area (both fee title and easement) using the GreenInfo Network (2008) protected areas dataset.

The parcel ownership dataset was also overlaid on the land cover and species' habitat datasets in order to calculate the area of each of these ecological components occurring within each parcel.

Additionally, for the giant garter snake and burrowing owl, the effective mitigation area (EMA) was calculated. For these species, compensatory mitigation can be accomplished either through preservation of existing habitat or restoration of previously converted habitat. Equivalent area units were required to allow the reserve selection algorithm to select the most efficient means to achieve mitigation goals for these species. The mitigation ratios were used to convert different land cover types to EMAs. Thus,

$$P_{EMA} = \sum_{i \in S} \frac{h_i}{r_i} \quad (1)$$

where P_{EMA} is the total EMA for an ownership parcel for a specific species, h is the total area within the parcel of a specific existing habitat type used by the species or is a restorable land cover type, r is the mitigation ratio quotient for that species, and S is the full set of habitat or restorable land cover types for that species. Therefore, if a parcel is selected for inclusion in the mitigation needs "solution", it can include both existing habitat and restoration potential.

Marxan reserve selection software (Ball and Possingham 2009) was used to evaluate each ownership parcel for potential use as a site for compensatory mitigation activity. Marxan uses spatial and attribute data for planning units comprising the analysis area (in this case ownership parcels) to find sets of planning units that meet the overall conservation goals (defined by the user) while minimizing the costs. For this analysis, goals were defined as the mitigation area needed to offset infrastructure project impacts to various regulatory species and ecological communities. We developed two sets of goals. The first goals were defined by the estimated project impacts and their associated mitigation ratios. The second goals were used to represent a longer range set of potential mitigation needs. The time horizon for these needs was set as five times longer than the time frame of the current planned projects. For these goals, we multiplied the DWR impacts by five to estimate this agency's potential impacts. For Caltrans projects, we assumed that new, currently unplanned projects could happen essentially anywhere within the study area. Thus instead of using the current projects as a baseline, we multiplied the total area of impact by five, but calculated impact to each regulatory species or land cover type as proportional to its overall area within the study region.

"Cost" refers to both economic cost of parcel acquisition and ecological cost. Here, cost was calculated from five input variables: road density (at a 3 km radius; U.S. Census Bureau 2007), urban area density (3 km radius; FMMP 2006), parcel area modified by a cost-per-area function (i.e. larger parcels generally have a lower cost-per-area value than smaller parcels; Thorne et al. 2009b), crop value (for agricultural parcels; ASFMRA

2007), and urban growth model outputs (Information Center for the Environment 2009, unpublished data; parcels likely to be developed will generally have a higher cost associated with them). These variables were combined where the factors were weighted by their perceived importance in affecting mitigations decisions. There are little data from which to derive a quantitative model for mitigation site selection, so we used expert judgment in setting the weights. The equation to set the total per parcel cost values is:

$$C_p = \sum F_w \tag{2}$$

Where the total cost *C* for each parcel *p* is the sum of all normalized cost factors *F* multiplied by a weight of *w*. The values of w were as follows: road density and projected development: 1, crop value and urban density: 2, and size of parcel: 10.

One further aspect of cost associated with each parcel is the effect of inclusion of the parcel on total boundary length of the set of selected parcels. As the overall boundary length increases, so does the cost of the solution. The rate of increase can be adjusted when running the model (through the “boundary modifier” function). For this analysis, we used five different boundary modifiers and ran the model using each, as we had no way to determine the most effective value for this modifier.

We ran Marxan 100 times (at 10 million iterations per run) under 10 different scenarios (short- and long-term with five different boundary modifiers each). This led to a total of 1000 runs. Each parcel was attributed with the total number of runs for which it was identified as part of a mitigation or restoration potential solution.

The final portion of the analysis focused on the integration of the mitigation activity with a regional ecological framework, or greenprint. We identified the greenprint by assembling the conservation priorities datasets obtained from agencies and non-governmental conservation organizations within the study area (organizations consulted were: DFG, TNC, Butte County, Placer County, Yuba County, and Sutter County). These were layered together and summed, so that for every raster cell (30 m x 30 m) in the study area, the total number of conservation efforts identifying that location as a priority was calculated. This is meant to be a simple way to represent conservation priorities for this study, but given differences in scale, conservation objectives and planning methods, areas selected by more conservation plans should not be interpreted as higher priority for conservation.

Next, both the Marxan results and greenprint results were normalized to a maximum value of 1.0. These values were then multiplied (resulting in values that also ranged from 0 to 1) and the ownership parcels were given a value equal to the mean value of the raster cells within their boundaries. This eliminated those parcels that either were outside of any identified conservation priority area or that did not contribute towards meeting mitigation needs. The highest values were thus given to parcels that were repeatedly identified in the Marxan analysis and addressed multiple conservation priorities.

RESULTS

A total of 21 Caltrans and 8 DWR future planned projects were identified in the study area. While the DWR projects were largely associated with channel vegetation and sediment clearing for maintenance of flood water capacity, the Caltrans projects varied in their type, ranging from surface rehabilitation to construction of additional lanes for traffic volume expansion. These projects combined to create an overall footprint of 1,742.2 ha, of which 500.8 ha were the result of Caltrans and 1,241.4 ha the result of DWR projects.

We calculated that this footprint would impact a variety of vegetation types and species that typically require compensatory mitigation actions (Table 1). The greatest impacts were anticipated to occur to riparian forest, with a total of 618.8 ha estimated to potentially be affected. Most of this impact (610.9 ha) was attributed to DWR channel maintenance projects. The species expected to be most affected by the suite of projects was giant garter snake, with 188.6 ha of habitat expected to be impacted by the infrastructure projects.

Table 1. Ecological components requiring mitigation activity in the study region, their typical mitigation ratio by type, and the calculated impact (under near- and long-term scenarios) due to agency infrastructure projects.

Target	Ratio - preservation	Ratio - restoration	Mitigation type	Short-term impact (ha)	Long-term impact (ha)
Freshwater wetland	3:1	1.1:1	both	54.6	397.0
Valley oak		2:1		61.3	333.9
Riparian forest	5:1	1.1:1	both	619.0	2,600.0
Blue oak		2:1		2.0	47.3
Giant garter snake	3:1	1.1:1	either/EMA	187.8	276.0
Swainson's hawk	1.1:1			102.1	197.3
Valley elderberry longhorn beetle		10:1		157.8	213.4
Burrowing owl	1.1:1	1.1:1	either/EMA	14.4	37.8
Bank swallow	2:1			156.8	65.0
Sandhill crane	2:1			0.0	9.3
Tricolored blackbird	2:1			72.2	34.6
Western yellow-billed cuckoo	2:1			25.4	30.3
Vernal pool - tadpole shrimp	19:1	1.1:1	both	0.5	30.0
Vernal pool - no tadpole	5.7:1	1.1:1	both	0.3	34.5

Mitigation ratios identified by regulatory agencies ranged from 1.1:1 for restoration actions to a maximum of 19:1 for preservation activity for vernal pools containing highly restricted, endangered, vernal pool tadpole shrimp. However, most preservation ratios were found in the 2:1 to 5:1 range (Table 1). When the mitigation ratios were applied to these impacts, a total of 6,539.8 ha of ecological offsets resulted; however, a good deal of overlap could occur in fulfilling these requirements. These offsets included both preservation and restoration activities. Significant mitigation actions identified included riparian forest preservation, riparian forest restoration, and valley elderberry longhorn beetle habitat restoration.

The Marxan analyses were run under two different temporal scenarios (near- and long-term) and five boundary modifiers, which led to two separate results, one for each scenario. For each, the results from the five runs were summed for individual ownership parcels, leading to a scale from 0 (the parcel was never selected as part of a solution) to 500 (every solution included the parcel) (Figure 4). Existing conservation areas were automatically included in solutions and thus received scores of 500. Parcels containing no ecological components designated for mitigation were excluded from analysis and received a score of 0.

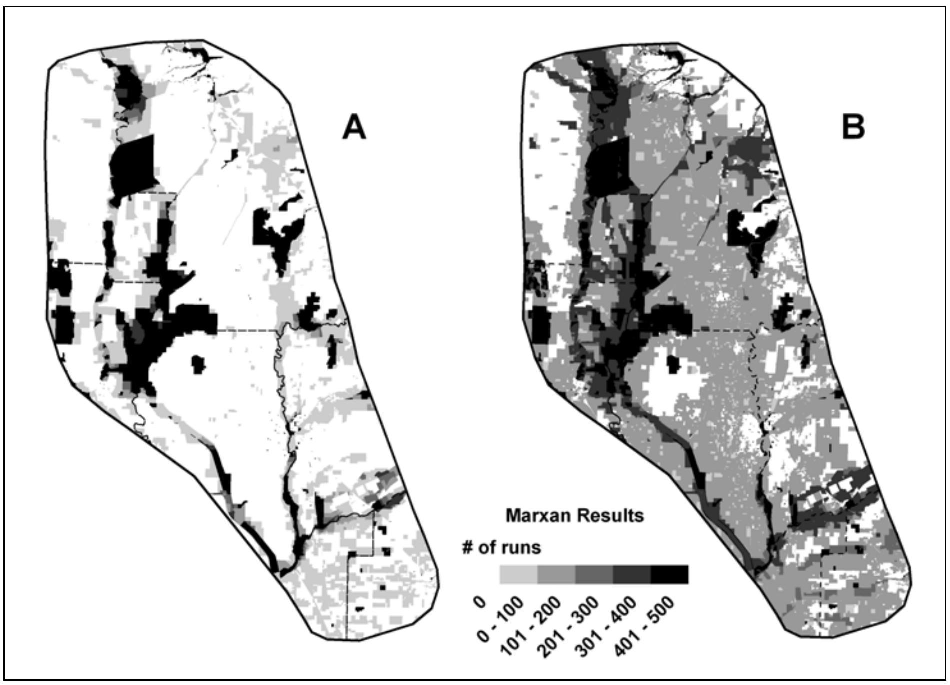

Figure 4. Marxan results for “cost effective” solutions to compensatory mitigation actions for: A) short-term scenarios, and B) long-term scenarios.

Areas identified frequently for mitigation activity under the near-term scenario included wetland complexes in the central portion of the study area (that helped link a number of existing conservation areas) as well as riparian parcels along the Sacramento River (in the western portion of the study area). When the analysis was conducted under a long-term scenario however, the focus of potential mitigation activity expanded to include more riparian areas in the west, vernal pool complexes in the northeast, the Sutter Bypass flood protection infrastructure in the southwest, and the Bear River riparian area in the southeast. These new areas were included in the long-term analysis as a result of the method used for calculating future Caltrans projects (that focused on the entire study area rather than simply current project locations). Thus these areas were included even though there was little identified mitigation needs in these areas in the short-term analysis.

The overlaid greenprint datasets were summed, leading to a conservation priority surface with scores ranging from 0 to 4 (Figure 5). The highest priority scores were found in the vernal pool complexes in Butte County and riparian forests in Butte and Glenn Counties. When the Marxan results for mitigation needs were integrated with the greenprint, there was little change in focal areas under the near-term scenario (Figure 6). Under the long-term scenario, however, the area of greatest value shifted to the Butte County vernal pool complexes. Other high value areas were the Bear River as well as Butte Creek (east of the Sacramento River in the western portion of the study area).

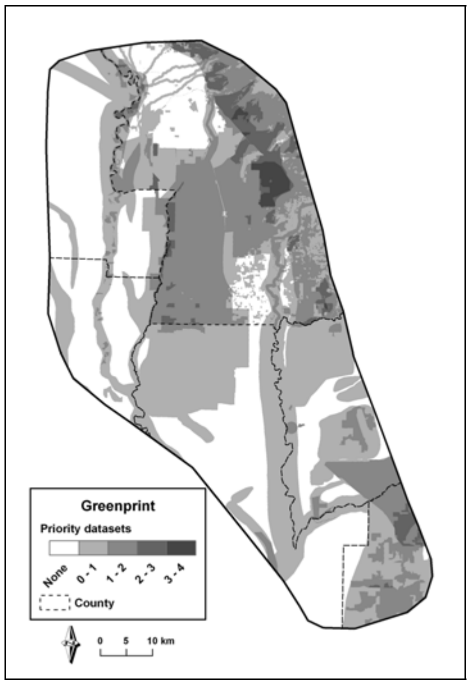

Figure 5. Study area “greenprint”, identified by overlaying priority area datasets from several organizations.

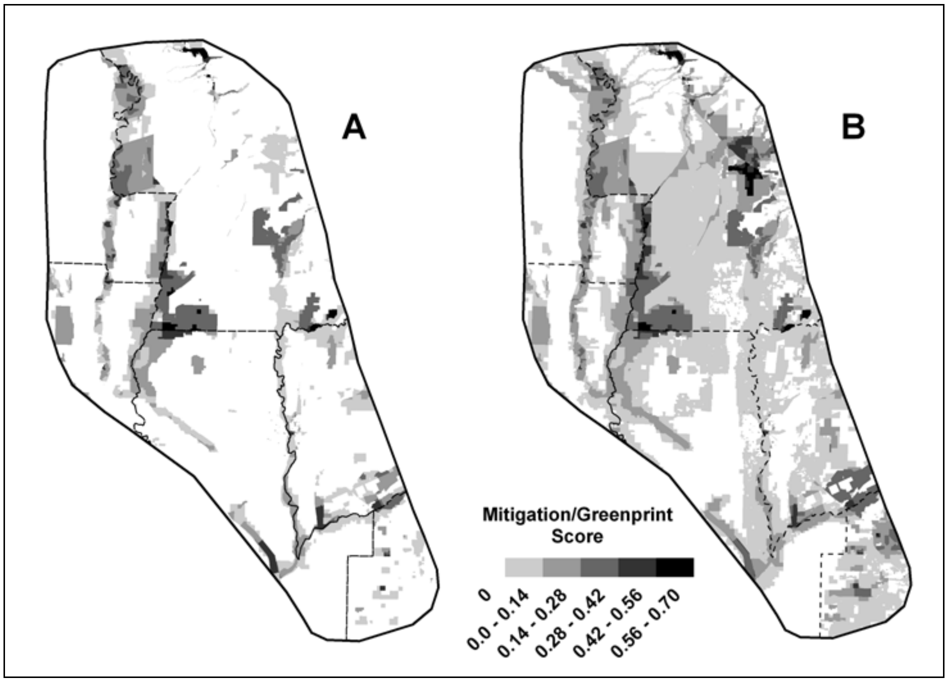

Figure 6. Overlap of mitigation needs analysis and regional greenprint. The darker shades indicate those areas that both meet mitigation goals across several scenarios but also contribute to meeting regional conservation priorities. Results shown here are for A) short-term scenario and B) long-term scenario.

DISCUSSION

We consider there to be a number of important planning elements addressed by this project. One element that has received attention recently is the potential benefits (ecological and economic) accrued when mitigation needs for several infrastructure projects are bundled into regional mitigation goals (Thorne et al. 2009b, Florida Department of Transportation 2001, Kiesecker et al. 2009b). This project serves as another example of this new direction in systematic planning of ecological offsets for infrastructure projects.

One important addition to the current literature on mitigation planning is the integration of mitigation needs of more than one infrastructure agency, with their different types of projects and mitigation needs. In this case, road maintenance and enhancement projects are coupled with flood channel capacity projects with their ecological effects and mitigation needs bundled within a specific region. This integration potentially allows for more systematic planning for regional ecological benefit. Additionally, this approach can also potentially lead to cost savings for the infrastructure agencies to an even larger extent than simple project integration within the agencies separately.

Another important element in our approach is the integration of the mitigation needs analysis with a regional conservation greenprint. The normalization of values and multiplication of the two datasets allowed us to identify parcels that would contribute to both agency mitigation needs and the overall ecological needs of the region. This will allow for the focusing of future mitigation actions towards those areas already identified as high priority by such efforts as regional Habitat Conservation Plans. When the greenprint analysis is coupled with the regional bundling of mitigation obligations, there will be the opportunity for infrastructure agencies to contribute substantial resources towards the implementation of regional conservation networks while concurrently meeting their legal mitigation obligations.

For this approach to be effective, it was necessary to accurately represent the actual mitigation obligations that the regulatory agencies would be likely to require of the infrastructure agencies. Informal discussion with regulatory agency personnel revealed that most obligations would consist of both habitat preservation and restoration. Thus our model needed to integrate these different types of activities. We were able to do this by treating these needs as separate ecological components. In addition, the use of the "effective mitigation area" concept allowed for an equivalency to be established when either type of activity would suffice to meet regulatory needs (e.g. giant garter snake mitigation). We feel that our approach was able to effectively represent the complexities of regulatory requirements in terms of mitigation ratios and types.

The inclusion of near- and long-term scenarios allowed for a more nuanced view of how mitigation needs might change over the course of time in the study region. Not only did overall area needed to meet obligations grow from near- to long-term, but the type of needs changed as well. While near-term needs focused on riparian forest preservation and restoration, for example, long-term needs shifted to include more vernal pool mitigation activity. The methods used here to calculate the long-term Caltrans mitigation needs allowed for the possibility of road projects throughout the region, rather than assuming that they would occur in the same types of areas. This approach then assumes that road project locations are somewhat stochastic in nature and that the current set of planned projects does not necessarily accurately represent the overall nature of projects in this region. The results of this project then can inform the planning process at several temporal scales and reflect different sorts of planning needs.

We encountered several issues while preparing the data for analysis that could serve as cautionary tales for others attempting similar efforts. The first major difficulty faced was the identification of applicable projects in the study region. The DWR projects were not assembled into a centralized database; identification and boundary delineation were accomplished through an ad hoc process by agency personnel. While the Caltrans projects were contained in a centralized database, there was little data on status of the projects. Discussion with regional agency personnel revealed that some of the projects and their associated mitigation actions had already been completed. Thus the final set of infrastructure projects included in our analysis were generally identified through a combination of existing datasets, communication with agency personnel, and GIS digitizing from aerial imagery, rather than being found in centralized databases.

A potential source of error in the analysis lies in the infrastructure project footprint calculation. The distances used to buffer the road centerlines for the Caltrans projects were taken from a table developed for projects across the state of California as a whole and was intended to be used as a state average for the project type. Thus the buffer distance used for the projects in the study region might not accurately reflect the actual affected area. DWR projects were delineated through analysis of aerial imagery rather than on-site, and thus may also display inaccuracies. Error in footprint delineation can lead to errors in the calculation of mitigation needs. On-site delineation of project boundaries would help alleviate this potential problem.

Further error could occur through the process of land cover classification based on the existing datasets to which we had access. These varied in accuracy (both spatial and thematic) across the study region. More effective mitigation needs analysis would be accomplished if there existed a comprehensive fine-scale land cover dataset for the whole study region.

One unexpected difficulty lay in the derivation of typical mitigation ratios required by regulatory agencies for various sorts of impacts. Contrary to expectations at the outset of this analysis, the ratios are arrived at on a case-by-case basis rather than through systematic application of predefined requirements. The ratios used here were based on interviews conducted with regulatory agency personnel and reflect their best interpretation of typical requirements. The actual ratios may vary as applied to specific projects. Much of the source of uncertainty in the derivation of mitigation ratios is due to the effects of spatial scale in the modeling process. Mitigation needs are generally calculated as the sum of effects on individuals of regulatory species. GIS modeling takes place on a landscape-scale, however. For instance, valley elderberry longhorn beetle (VELB) mitigation needs are derived through impacts to elderberry bushes used by VELB and involve calculating the number of stems impacted and new bushes that need to be planted. We translated this to a 10:1 ratio at the landscape-scale, but this is a rather crude generalization of the implementation patterns of compensatory mitigation for this species.

A bias may also occur in identification of the greenprint used for integration with the mitigation needs analysis. The datasets used were those to which we had access and thus did not necessarily represent all of the major ecological features that would comprise an ideal greenprint. For example, there were priority areas identified in ongoing HCP efforts for two counties in the study region (Butte and Placer) that were included in the greenprint. Two other counties (Yuba and Sutter) have an ongoing HCP process but to date have not identified priority areas. The final two counties (Colusa and Glenn) are not engaged in HCP planning currently. Thus priority weighting will shift towards the two counties with identified priority areas in the final greenprint. It is easy to assume that a place with more planning processes selecting it is a higher conservation priority than one with fewer plans prioritizing it, but this would be mistaken interpretation. There is no element of risk of loss in this prioritization, so a higher-rated area may have been selected by multiple plans, but may be relatively well protected already. Additionally there are other private conservation organizations that may have priority areas identified but were not able to be contacted or were missed in the project scoping process. An ideal greenprint would be comprehensive in nature and conducted with consistent goals and spatial data.

Despite these potential issues, we feel that this analysis represents an important next step in integrated mitigation needs planning. There are some additional steps that could lead to an even more robust analysis. One would be to include wildlife and landscape connectivity explicitly in the greenprint identification. While there are ecological features that serve as proxies for some aspects of connectivity (e.g. riparian forest preservation), there is a lack of comprehensive analysis of this important conservation feature. This should be included in the next phase of this project.

A further point of inquiry would be a comparison of the effect of bundling the multiple agency requirements (as was done here) with treating the agencies separately. This would help elucidate what specific benefits (if any) accrue when combining the mitigation needs of the agencies. This would effectively test one of the assumptions made at the outset of this analysis (i.e. the effectiveness of mitigation bundling).

A similar analysis would test the assumption that regional bundling of project needs actually leads to cost savings and ecological benefit. A useful analysis would examine the effects of selecting parcels using the overall project footprints versus the project-by-project status quo. If benefit is found (as we would expect it to be), this analysis could serve as a useful tool in creating interest in other agencies for participating in this sort of comprehensive mitigation planning.

One potential partner that could be approached with the results of this sort of analysis would be local and county transportation agencies which are responsible for the majority of the road projects within our study area (and other regions as well), but were not included in this state-agency based assessment. If there are demonstrated benefits in regional advance mitigation, there is a potentially greater likelihood that mitigation activity from many more road projects could be incorporated into this process, leading to even greater integration of mitigation action with regional conservation needs.

This analysis demonstrates one means through which ongoing mitigation needs of multiple infrastructure agencies can potentially be incorporated within the overall conservation network within a given region. This has the potential to lead to a more ecologically effective use of public funds and to help achieve regional conservation goals. There will also likely be a concurrent fiscal savings. If an effective process is implemented, there is further potential for collaboration with other organizations with mitigation requirements. While these actions alone will not lead to fully realized regional ecological networks, they can contribute substantial resources over the long-term towards meeting regional ecological conservation goals.

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