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APPENDIX A-2

Reserve Design Concepts and Tools

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A.1 Introduction

A summary of basic conservation biology tenets and reserve design concepts is provided below, along with a description of some of the tools available to support the reserve design process.

A.2 Reserve Design Concepts

Although many factors can be incorporated into reserve design, the most widely used are diversity, rarity, naturalness, size and representativeness (Margules et al. 1988). Other important concepts often addressed include the island biogeography design principles of MacArthur and Wilson (1963 and 1967): (1) area effect—the larger the reserve, the greater the species richness (more total species) and the greater the chances of long-term viability of populations (due to more individuals and local populations); (2) isolation or distance effect—the less the distance between reserve units, the greater the opportunity for gene flow, colonization, and rescue effect (e.g., also see Brown and Brown-Kodric 1977); (3) species equilibrium—the number of species that an area can support is determined by a balance between colonization and extinction; and (4) edge effect—the larger the ratio of reserve area to reserve perimeter, the lesser the edge effect.

Edge effect is particularly important because of the multiple issues it raises, from reserve size and shape, to land use planning and zoning of land uses adjacent to reserve areas. An edge effect is defined as a change in the "conditions or species composition within an otherwise uniform habitat as one approaches a boundary [edge] with a different habitat (Ricklefs 1993)." Edge effects at the boundary between natural lands and human-occupied lands ("urban edge effects") arise due to human-related intrusions such as lighting, noise, invasive species, exotic predators (dogs, cats, and opossums), hunting, trapping, off-road activities, dumping, and other forms of recreation and disturbance. Although some species are in some ways unaffected by edges [e.g., reproductive output of the rufous-crowned sparrow (Morrison and Bolger 2002), distribution of arthropod species (Bolger et al. 2000)] or even show preferences for edges (e.g., indigo buntings and northern cardinals in Woodward et al. 2001), human-induced edge effects are generally unfavorable to native species.

Another important feature of reserve design is the spatial arrangement of wildlife movement corridors and linkages between core areas. At this point, it is useful to contrast movement corridors with linkages. Movement corridors are often linear and facilitate efficient movement by providing adequate cover and lack of physical obstacles for movement (Beier and Loe 1992). Movement corridors do not provide "live-in" habitat for species. Linkages, in contrast, are areas providing permanent resident live-in habitat as well as movement habitat for a particular species. Linkages contain resources that meet the life history requirements for the species the linkage is intended to serve. Known as landscape linkages, these areas are capable of sustaining a full range of community/ecosystem processes, thus enabling gene flow via seed dispersal and animal movement over a period of generations. Each habitat connection may be defined as a corridor or a linkage for each species.

Connectedness through landscape linkages and movement corridors is important because lack of connectedness (habitat fragmentation and isolation by distance) can increase the likelihood of extinction of local populations and therefore is one of the most serious threats to biological diversity. The probability of local extinction (known as extirpation) becomes greater as immigration and emigration to and from a reserve area are impeded by conversion of natural habitat between occupied or potential habitat patches to inhospitable land covers. Linkages, therefore, serve to ameliorate habitat fragmentation and isolation by permitting the following: (1) the travel, migration and meeting of mates for wide-ranging animals; (2) plant propagation; (3) interchange of genetic material; (4) movement of populations in response to environmental changes and disasters; and (5) colonization of available habitat by individuals (Beier and Loe 1992).

Careful consideration and application of these tenets of reserve design could help ensure that the desert-wide conservation analysis and the DRECP reserve design are comprehensive, connected, and resilient to climate change, as recommended by the DRECP Independent Science Advisors (DRECP ISA 2010). As stated in the Independent Science Advisor report (DRECP ISA 2010),

> *"The resulting reserve network should capture the diversity of natural communities and environmental gradients in the plan area, protect rare communities and special features, conserve core population areas for Covered Species, conserve habitat linkages and movement corridors between core areas, and be buffered against indirect impacts of human influences."*

A.3 DRECP Reserve Design Tools

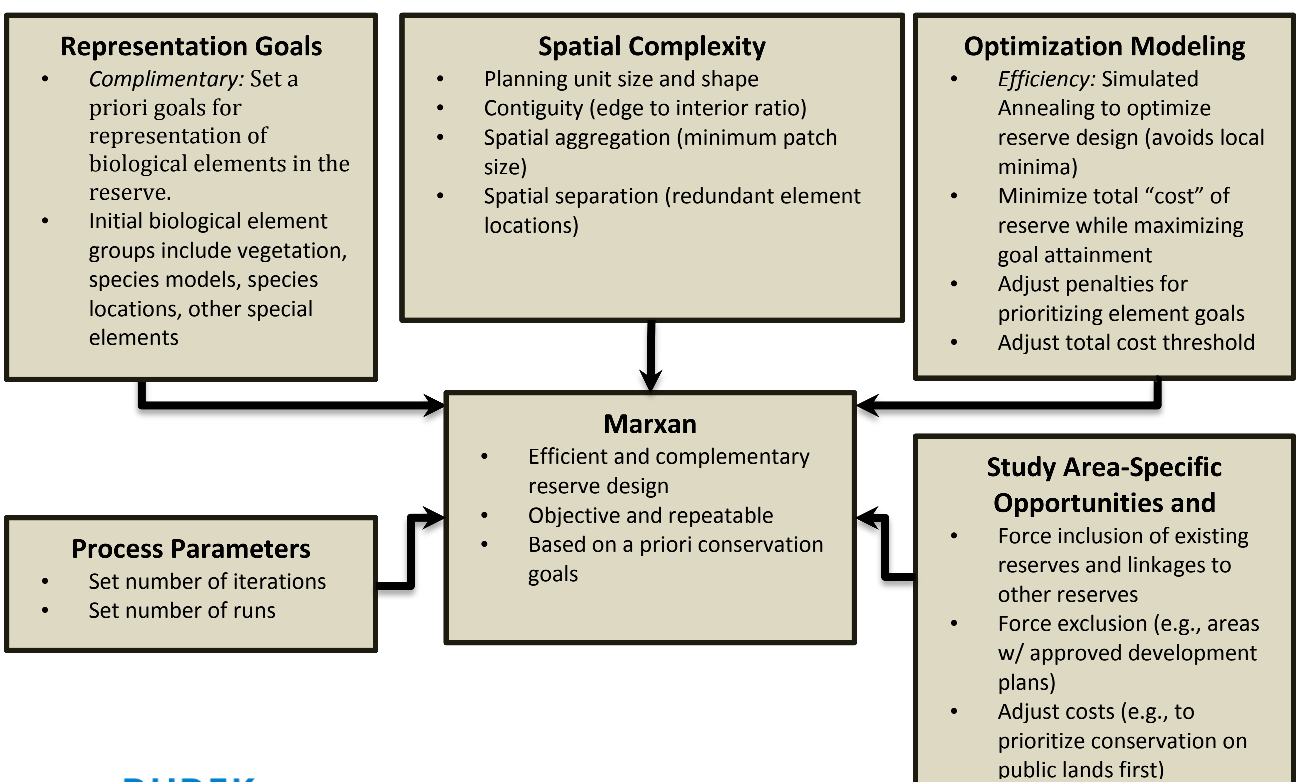
The primary tools available for reserve design in the DRECP Plan Area include computer-based reserve selection algorithms such as Marxan and Zonation, regional conservation analysis databases such as BIOS and ACE-II, and connectivity modeling such as Corridor Designer and least-cost path analysis. These tools are discussed below with regard to how they are or could be used to compliment the DRECP reserve design process.

A.4 Marxan Reserve Selection Algorithm

Marxan and Zonation are the reserve design software recommended in the DRECP Independent Science Advisors report (DRECP ISA 2010). The DRECP consultant team is currently using Marxan to develop initial reserve design configurations for a number of scenarios.

Marxan is a computer-based reserve selection algorithm that is being used to develop an "optimized" reserve design for the DRECP. Marxan incorporates basic scientific principles of reserve design (biological cores and linkages, consideration of edge effects, conservation goals for representation of species habitat, occurrences, natural communities, and ecological processes) to identify and assemble the basic structure of the reserve design. Marxan is a preferred approach because it allows the incorporation of *a priori* identified biological goals and objectives for biological elements (i.e., species, natural communities, and physiographic features representing ecological processes such as hydrogeomorphic dynamics). Additionally, Marxan is adaptable to include existing patterns of ownership and land management status, and allows weighting and prioritization of planning units and biological elements to match the relative importance based on science and stakeholder input. Figure A-1 depicts the various components considered during a Marxan run.

Figure A-1. Components of the Marxan Reserve Selection Tool.



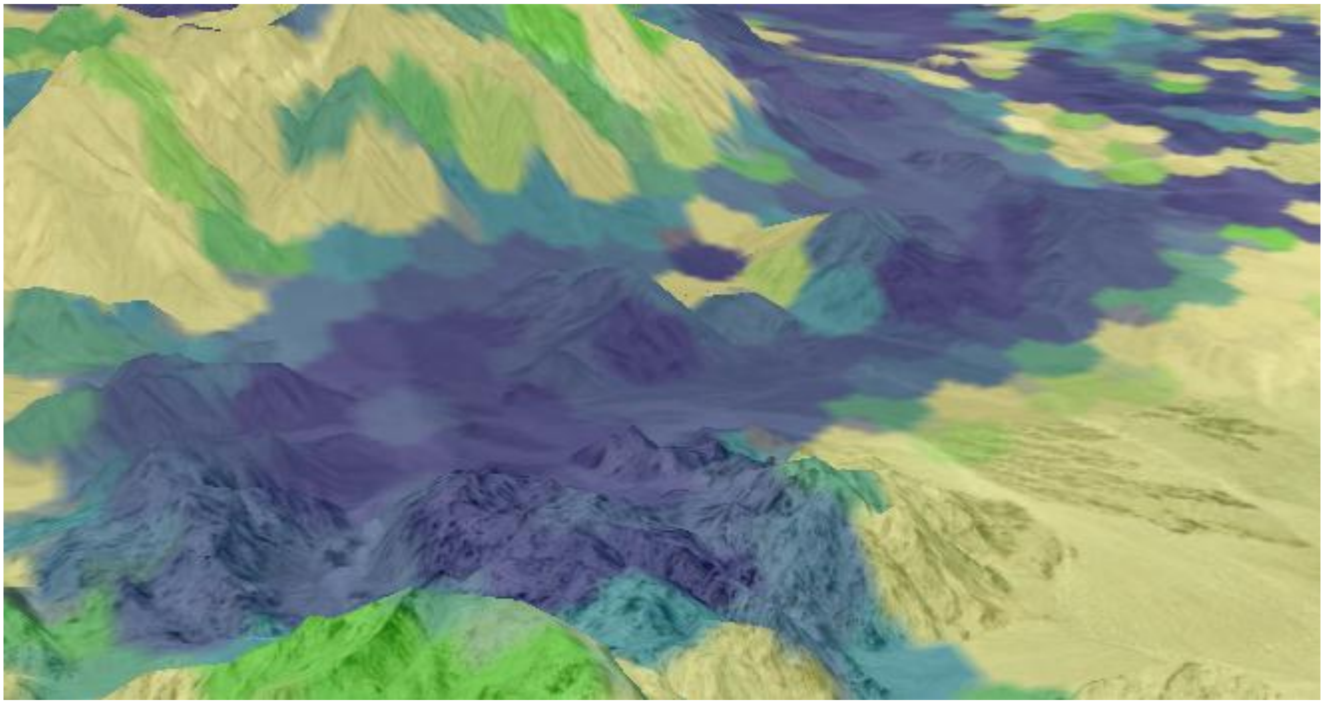
Marxan is an optimization algorithm. Marxan works to find a reserve design that most efficiently meets the biological goals that have been set for each of the biological elements it has been given to consider. While a conservation biologist with a solid understanding of the scientific principles of reserve design could design an effective reserve for one, or even several species, the task gets considerable more complex when trying to efficiently design a reserve to protect upwards of a hundred species and scores of natural communities. Marxan is able to simultaneously consider hundreds of species and communities and any other biological elements for which conservation goals have been set and identify a highly efficient reserve design that simultaneously meets the conservation goals for each biological element (species, natural community, etc.). Marxan is able to do this by sampling the Plan Area landscape a million times with a random reserve design and iteratively comparing each sample to the next and keeping the one that is more efficient in meeting the biological goals. This random sampling reserve simulation process (call simulated annealing) is able, through iterative improvement, to identify a very efficient reserve design.

Marxan compares each iterative sample with the next in terms of a reserve optimization function. As shown below in Table A-1, the optimization function calculation for each iterative sample is a unit-less number that represents the sum of the area, plus the sum of any penalties for not achieving the conservation goal for each biological element, plus the sum of the boundary length value. A smaller calculation of the Marxan optimization function means a more efficient reserve design. A sample Marxan reserve design output for DRECP is shown in Figure A-2.

Table A-1 Optimization Function Calculation

Marxan Optimization Function	=	Area Calculation	+	Missed Goals Penalty Calculation	+	Boundary Length Calculation
Smaller value is more efficient reserve design		Increases with size of reserve		Increases with number of missed goals and amount by which each goal is missed		Increases with larger edge to interior ratio

Figure A-2 Sample DRECP Marxan Reserve Design Output. Blue areas are indicated inside the reserve, while light green and yellow are outside the reserve.



A.5 BIOS and ACE-II

The CDFG has been developing a number of conservation planning tools that are of use in the reserve design process, including Biogeographic Information and Observation System (BIOS) and Areas of Conservation Emphasis (ACE-II). BIOS is a system to facilitate the management, visualization, and analysis of biogeographic data throughout the state. There are hundreds of datasets included in BIOS, many of which occur in the DRECP Plan Area. BIOS would be useful in the DRECP reserve design process to ensure that all available biogeographic datasets have been evaluated are current and up to date. BIOS allows the user to enter spatial queries and text queries so data can be searched and obtained by area or by species or other biological resource name.

CDFG's ACE-II program was initiated in 2009 to help guide and inform conservation priorities throughout the state. ACE-II includes the current results of many biogeographic analyses and syntheses of data to determine the distribution of biological richness (including species diversity, rarity, and habitat sensitivity). The set of tools in ACE-II allow the user to summarize data and display spatial information important to conservation decision making. The conservation tools and analytical results provided in ACE-II would be evaluated and compared to the DRECP analyses and reserve design process, and would be used to supplement the DRECP information as the reserve design and conservation strategy continue to be developed.

A.6 Corridor Designer and Least-Cost Path Analysis

There have been several projects in recent years that are evaluating the high priority areas for connectivity through California's deserts. Several of these projects have included wildlife corridor modeling using software like Corridor Designer that use least-cost path analysis to identify primary wildlife corridors for individual and sets of species.

The California Essential Habitat Connectivity Project used this approach to identify large remaining blocks of intact habitat or natural landscape and model linkages between them that need to be maintained, particularly as corridors for wildlife. Over sixty federal, state, local, tribal and non-governmental organizations collaborated in the creation of:

1. A statewide wildlife habitat connectivity map using a Geographic Information System (GIS) based modeling approach;

2. An assessment of the biological value of identified connectivity areas; and

3. A strategic plan that helps varied end users interpret and use the statewide map and outlines a methodology necessary for completing connectivity analyses at finer spatial scales.

Other connectivity projects are ongoing, including the South Coast Wildlands California Desert Connectivity Project. Results of this project are not yet available.

These analyses would be used to supplement the DRECP information as the reserve design and conservation strategy continue to be developed.

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