❖Standard 11: Design ecoregional portfolios/biodiversity visions to best meet goals for all conservation targets/ biodiversity elements, using the principles of efficiency, representation, irreplaceability, and functionality. [PLAN]

Rationale

Ad-hoc conservation is blind investment and lacks context. A comprehensive vision (portfolio) should identify a suite of places that contains occurrences of biodiversity targets/elements that are necessary to conserve biodiversity representative of an ecoregion. This vision/portfolio should ensure that the relative contributions of an investment strategy are understood in a regional context. Conservation assessments need to be current to define the present arenas for actions in a comprehensive yet efficient way to inform our actions and those of partners and stakeholders given the changing landscape of biodiversity patterns, threats, and conservation opportunities. In addition, visions/portfolios are the framework for measuring conservation progress within an ecoregion.

Recommended Products

- Description of design goals, criteria, approach, methods, assumptions, tools and rationales.
- Assessment of the conservation management status of lands and waters (e.g. IUCN protected/managed area categories, management strategies such as fire and sustainable water management, invasive species control, etc.).
- Approaches and tools used to generate vision/portfolio (e.g. expert workshops, optimization tools such as SITES, SPOT, MARXAN, EPAT) and rationales.
- For cases where optimization tools have been used, clear descriptions and rationale for inputs and values such as cost surfaces.
- Shape files and maps of areas of biodiversity significance and patterns of threats. Include alternative risk and updated scenarios where available.

GUIDANCE

One of the final products of an ecoregional assessment/vision is a set of areas of biodiversity significance which define a solution set to most efficiently and effectively conserve the biodiversity of an ecoregion. These areas are collectively called a portfolio or a vision. These areas are not conservation sites in the sense that they define the places where all strategies need to be implemented. They do not provide accurate boundaries for protected area design, or for maintaining corridors and functional landscapes. These are products of more detailed, finer-scale assessments. The areas that are mapped are locators for the places that contain the things we are interested in conserving. We refer to them as *areas of biodiversity significance.*

The portfolio is one version of a solution set to represent comprehensively, the biodiversity of an ecoregion in an efficient and effective manner. Portfolios are designed to best achieve the conservation goals set for targets in the least number of places and areas of lands and waters. Current conservation and resource management practices, land ownership, levels of threats, and costs of implementing conservation actions are all considered when selecting geographic priorities for a portfolio.

Portfolios are created to focus conservation actions on those places that will make the greatest contribution to the comprehensive conservation of the biodiversity of the ecoregion. They create a common focus to galvanize actions among many conservation and resource management partners. Portfolios are not merely maps. They include all of the underlying data that provide information on the species, communities, ecological systems and other targets that reside in the area of biodiversity significance. Portfolios contain information on target location, ecological processes maintain targets, and target viability/integrity. Additionally, they contain information on the scope and severity of threats among the area of biodiversity significance, current levels of protection, stewardship and management. Collectively, this data is helpful for informing priorities for actions, development of area-based and multi-area strategies, and measuring success.

Designing ecoregional portfolios or visions requires understanding:

- The principles of portfolio/vision development
- The general process to create a portfolio/vision
- Multiple scenarios
- Conservation outside of the portfolio/vision
- Integration of marine, freshwater and terrestrial portfolios
- Updating and revising portfolios/visions
- Tools for designing portfolios/visions

Principles of portfolio/vision development

There are several elements that we consider an integral part of portfolio development. Portfolios should be assembled to maximize effectiveness, representation and efficiency, integrate marine, freshwater and terrestrial targets and minimize implementation costs. These elements are defined as:

- **Effectiveness-** Represent the greatest number of viable occurrences of all fine- and coarse-scale targets in the ecoregion that either achieve or make progress towards numerical conservation goals. Effectiveness can be achieved by selecting areas based on coarse-scale targets first and then fine-scale targets, or vise-versa. Since they are not expected to be correlated, the steps in the process should not matter.
- **Representation-** Capture multiple examples of all conservation targets across the diversity of environmental gradients appropriate to the ecoregion in accordance with distributional goals (e.g., ecoregional section or subsection, ecological land unit (ELU), ecological

drainage units, zoogeographic sub-units or some well defined biological or physical gradient).

- **Efficiency-** Capture the most viable occurrences of targets in the least number of places and in the smallest area across the ecoregion. This results from selecting areas that contain multiple targets, often at multiple scales, such as ecological systems, communities and species targets in the same place.
- **Integration-** Give priority to sites that contain high-quality occurrences of terrestrial, marine and freshwater targets. This could be considered efficiency.
- **Cost**- Design the portfolio to be comprised of those places that are least threatened and the lowest cost of implementing conservation strategies.

The General Process to create a Portfolio/Vision

Portfolios are generally derived from a set of processes that define a number of alternative outcomes and reviews and refinements of them. These outcomes are intended to most efficiently and effectively make progress towards conservation target goals. When there are many options for where to identify lands and waters that contain different combinations of species, communities and ecological systems, the viability/integrity of targets, the degree of threats to them, their proximity to each other, their inclusion or proximity to existing protected lands and waters, and the importance that different targets are given, all play into the solutions that are generated.

Areas of biodiversity significance and the portfolio as a whole are developed using information on targets and their occurrences. Different weight is often given to different target types or targets with different attributes. For instance, highly threatened and endangered species with a G1 ranking might be given a higher weight than a G3 species. An endemic ecological system may be given a higher weight than a common and widely distributed one. This does not mean that the lower weighted targets are not included in the portfolio. When using optimization programs, targets that have higher weights are put into the portfolio first, and other targets are selected to fit their context in an efficient and effective manner.

Landscape information on threats is generally used to create a cost layer for portfolio design. This informs scenarios to create a portfolio that takes into account the potential risk and cost of conservation actions, in addition to the efficiency and effectiveness of capturing conservation targets. One of the major threats to biodiversity is global climate change. The Nature Conservancy's Climate Change Initiative has recently developed data and methods to incorporate the potential impacts of climate change into portfolio design. While not wide spread, this information should be taken into account when developing portfolios. An example is presented as a case study.

Another important source of information on cost is protected and managed areas. It is often assumed that protected areas and many managed areas already confer sufficient or significant conservation protection to biodiversity targets and therefore have no, or very low cost associated with them. Using these as "seed" areas allows initial focus for portfolios by including target examples that are already protected, and provide opportunities to build upon them as core conservation areas. The process of using this information is analogous to conducting a GAP analysis, where the types of conservation targets and the number of examples that exist in protected areas, in well managed areas for biodiversity conservation, or are under some form of conservation management are assessed, and additional areas are identified to fill in the "gaps" in conservation. The process used to develop a portfolio takes it one more step by using the current areas that confer conservation management and using them to influence the design of the portfolio. See the Measures Unit for guidance on conducting a GAP analyses and developing information for this process.

A great need which has lacked focus and development has been designing ecoregional portfolios using design goals to create and maintain functional areas of biodiversity significance and landscapes within ecoregions. Integrating the needs of targets for connectivity, natural disturbance regimes, environmental heterogeneity and other landscape processes and patterns has been lacking in most ecoregional portfolios. Many conservation planners suggest that design goals are a second phase akin to site conservation area planning, and require more detailed information and assessments. This may be true, but there is room for initiating the process at the initial portfolio design state.

A last component that has been lacking in most ecoregional portfolios is restoration areas. In highly impacted ecoregions, restoration is the only option to achieve conservation goals for many targets. Defining the specific places to implement this strategy can provide much needed focus for conservation investment. Careful evaluation of restoration potential and target needs is necessary to develop this component of a portfolio. See links to restoration guidance in the resource section.

Multiple Scenarios

It is not uncommon in relatively intact landscapes to have many solution sets, or scenarios for portfolios. Another situation which generates multiple solutions is the use of varying goal scenarios based on different levels of risk. Generally, multiple risk scenarios with different solutions in fragmented landscapes build upon a basic set of areas, as opposed to multiple scenarios in intact landscapes where there are a multitude of target occurrences to choose from. In each of these cases, optimization programs are generally used to generate scenarios which are reviewed by experts to refine and generate a portfolio. In some cases, multiple sets of portfolios for the same ecoregion are generated.

In highly fragmented landscapes, there are often few if any alternatives for a portfolio. Many portfolios in these landscapes are generated without the assistance of portfolio assembly programs. However, the same expert input and review are required and underlying data exist in these portfolios as well.

Conservation outside of the portfolio/vision

Multiple portfolios can create confusion when discussing sets of priorities for conservation actions. However, many stakeholder's priorities may not be included in a given portfolio even if they contain examples of many of the targets. This situation can arise for many reasons. The examples of those targets may not have the highest viability/integrity ranks, or have the lowest levels of threats affecting them. At the scale of an entire ecoregion, these examples might not be the most efficient places to work. They may be places that contain single species, as opposed to having those species in areas where many other target species occur. The portfolio does not preclude incorporating the contribution of conservation actions on lands and waters that are not in the portfolio.

Many stakeholders are limited where they can work, and are already conducting actions outside the portfolio. The ultimate measure of conservation progress is the extent of the effective conservation of viable target examples in relation to goals, and there are often examples that are not within the portfolio which can contribute to this. This situation is not uncommon and can be dealt with in several ways. When developing portfolios, optimization outputs are not seen as the ultimate portfolio. Including areas that have viable target examples that are under management or actions of partners and stakeholders that are probably going to implement conservation actions can be included in the portfolio. Another approach is to generate scenarios based on current and potential future conservation actions. This allows real-time portfolios/visions to be generated based on alternative courses of actions. These portfolios can be tailored to specific partners and stakeholders, and create a custom portfolio which provides a focus for a sub-set of the partners and stakeholders in the ecoregion. The most important aspect of any of these approaches is that the contribution of any conservation actions to viable target examples is tracked, and the impact to potential future portfolio design is assessed.

Integration of marine, freshwater and terrestrial portfolios

Portfolios are commonly created separately for freshwater, terrestrial and marine targets. Strength in this approach is that the optimal solution for each realm is not compromised by other realms. A technical issue is that terrestrial, freshwater and marine ecoregions are distinct polygons, and developing portfolios for targets based on the separate ecoregional frameworks stays true to the ecology and the abundance and distributional (stratification) goals set for the taxa that comprise the different realms. Results from separate portfolios are overlaid and a grand portfolio for a region can be generated.

Alternatively, integrating these different realms from the beginning can result in a more efficient portfolio, and provide a better ability to focus conservation actions which integrate terrestrial, freshwater and marine ecosystems much more effectively.

This approach is probably best taken in more intact landscapes where there are options for terrestrial, freshwater and marine priorities, and integrated options can be achieved without compromising the targets of any realm.

Updating and revising portfolios/visions

Portfolios/visions should be updated when there are new data available, or review and partner or stakeholder input that suggest potential for changes in the focus of conservation actions. These data include new information on viability, threats, protected/managed areas, conservation actions, biodiversity surveys and other information. The time frame for updating information and evaluating a portfolio/vision is dependent on the degree of change in the patterns represented by the data, and their potential impact to change the foci for conservation actions. Updates to portfolios/visions should not necessarily require the level of analyses conducted to generate the first iteration of the portfolio, but they may. Areas of biodiversity significance can be added when data identify additional examples of targets that meet criteria for inclusion. These examples may arise from discovery of new examples or examples that have had their viability and threats change to levels that meet criteria for inclusion. Areas may be omitted because the examples of targets have had their viability and threats change to levels that no longer meet criteria for inclusion. The amount of new information and degree of change in ecoregions will ultimately determine the degree of analyses that should be conducted.

Tools for portfolio/vision design

Portfolio design techniques range from solely engaging expert knowledge and opinion to using computer assisted algorithms to solve complex calculations. All approaches provide a set of options that should be reviewed by and acceptable to partners and fulfill the principles of portfolio design.

Expert workshops engage scientists who have knowledge regarding species, ecosystems and geographical areas. Virtually all ecoregional assessments and biodiversity visions are developed with the supporting knowledge that experts provide, regardless of the extent of reliance on computer algorithms. Some assessments rely more heavily on experts to provide information on conservation targets or to help define the important areas that should be part of the portfolio of sites.

There are a variety of computer-assisted portfolio development tools. Each one has its strengths and weaknesses and different levels of complexity. However, the computer assisted tools use the same principles and produce comparable results. The choice of tools should be based on information availability and the level of complexity being addressed. The Conservancy has used computer assisted portfolio development and optimization tools such as MARXAN, SITES, SPOT and to a lesser extent, EPAT and C-PLAN. EPAT is a computer assisted portfolio design tool that keeps track of the targets that have been incorporated into the portfolio. The other four tools are optimization programs that have been used for point, linear and polygon representations of targets. Regardless of the specific tool chosen, the best results occur when computer algorithms are combined with expert knowledge.

Expert workshops

Portfolios developed with expert knowledge as the primary or secondary source of information on the biodiversity have certain caveats. Experts may be biased towards certain taxonomic groups or limited to very specific geographical areas. However, in situations where data is limited or not very reliable, experts not only provide data on conservation targets, goals, condition, distribution, ecological processes, viability but also aid in the portfolio design itself and evaluating the results.

The Nature Conservancy has developed over 40 ecoregional assessments with expert workshops as a primary tool for portfolio development. Most of these workshops were supported by GIS data analyses prior, during and after the workshops (overlays, buffers, biodiversity index, etc.). At the workshops, experts are asked to provide geographical distribution of conservation targets, the condition of these targets, potential threats to the conservation target, among other information. Once the information on conservation targets has been analyzed, experts review the proposed portfolio and may provide additional information to support site Conservation Action Planning input on site-specific threats, opportunities and strategies. This step is more common when there is a limited amount of data that need the review of experts. GIS analysts and data managers must work closely with the experts to ensure that all data is captured and appropriately stored for further analysis.

Other teams use expert workshops to derive their entire portfolio by consulting experts and requesting them to draw the areas they consider important on paper maps or GIS layers. These expert-derived drawings are later digitized and analyzed with available data to confirm that the portfolio achieves the principles of portfolio design. This step is more common when conservation target data is virtually non-existent and/or when resources (GIS experts, GIS equipment, data acquisition, etc.) are scarce.

Expert workshops are an opportunity to have peers and partners provide not only information regarding targets and their condition, but also the opportunity to provide input and refinement to the development of the portfolios which may be at the stage of an optimization output from a computerized algorithm. Data management of the information that is gathered during these workshops is critical to further update the portfolios when more data is available.

Portfolio Selection Software

What follows is a description of the most frequently utilized software programs used to assist the portfolio design process for ecoregional assessments. Choosing the best tool for portfolio design in any ecoregion requires the consideration of the condition of the landscape, data availability, and desired outcomes. Further information pertaining to each of these tools can be found in the Case Studies, Tools and Resources sections of this document.

SITES

Sites 1.0 is a customized ArcView project that facilitates designing and analyzing alternative portfolios. The software in Sites 1.0 to select regionally representative areas of biodiversity significance for the conservation of biodiversity is called the Site Selection Module (SSM). It is a streamlined derivative of SPEXAN 3.0 (Spatially Explicit Annealing) that was developed by Ian Ball and Hugh Possingham. SPEXAN was originally developed as a stand-alone program with no GIS interface for displaying portfolios and ancillary spatial data. The model was applied in two TNC ecoregions--the Idaho Batholith and the Northern Sierra Nevada.

12 TNC assessments in the US and abroad have used this tool.

SPOT

SPOT is a newly coded software based on SITES using the same methodology and criteria to develop the optimization. In SPOT, only the simulated annealing algorithm is used and has been improved by re-writing the code using LANGUAGE, instead of SITES LANGUAGE. Annealing is the more accepted of the algorithms (PUBS). SPOT is completely integrated in a GIS (ESRI's ArcView 3.x) as a menu with functions that include the creation of analysis units and development of conservation target lists. The integration in ArcView has enabled this tool to become very streamlined and in addition, because of some tools to assess results will produce quality controlled and comparable results. SPOT version 1.0 was rolled out in 2003. No comprehensive testing or comparisons have been developed, but some ad-hoc tests comparing SPOT, SITES and MARXAN have revealed that further testing needs to be completed, but have also pointed out that the accuracy and reliability of the tool is acceptable. The programming team has tested the tool extensively and has fixed a first set of bugs that are detailed in the tool installation and licensing text. The Nature Conservancy's Conservation Systems Office holds the comprehensive development product package delivered by the programming team.

MARXAN

MARXAN is software that delivers decision support for reserve system design. MARXAN finds reasonably efficient solutions to the problem of selecting a system of spatially cohesive sites that meet a suite of biodiversity target goals. Given reasonably uniform data on species, habitats and/or other relevant biodiversity features and surrogates for a number of planning units (as many as 20,000) MARXAN minimizes the cost (a weighted sum of area and boundary length, Possingham, Ball and Andelman 2001) while meeting user-defined biodiversity targets.

EPAT

The Ecoregional Portfolio Assembly Tool (EPAT) is a decision support tool for assembling an ecoregional portfolio. It is best used in regions where conservation options are somewhat limited. EPAT has a number of features that indirectly support the portfolio assembly methodology, including the display of GIS data, information management enhancements such as integration with the Conservation Planning Tool, and a number of reports that give meaningful insights into the results of the assembly process. EPAT is a standalone application written in and requiring Microsoft Access 2000. It uses CPT data stores as a source for all data. When connecting to a CPT dataset for the first time, EPAT will make some modifications to the table structure to enable the storage of EPAT-specific data as well as GIS information, which CPT is not normally capable of storing. EPAT uses Map Objects to provide integrated mapping capabilities, and is able to use geographic data from a number of sources and integrate it tightly with CPT's tabular data model.

C-PLAN

Developed by New South Wales National Parks and Wildlife Service, C-Plan is a system designed to support conservation planning decisions.

C-Plan is a windows based software package that when linked to a GIS can display the relative contribution (Irreplaceability and other measures) of land areas (sites) towards a predefined conservation goal. These contribution measures are derived from a biological database containing modeled species or forest distributions and/or actual survey results. The conservation goal takes the form of targets assigned to individual biological entities (features) within the landscape.

C-Plan is interactive in the sense that it can recalculate and redisplay these measures when one or more sites are earmarked for protection (by selecting sites on the GIS). All recalculations take any changes into account (sites that are selected or deselected for protection) and the result is mapped back onto the GIS to display a new pattern of options. The level of protection assigned to an area can be varied (note that this is still being developed to incorporate zoning for different land use zones).

OPPORTUNITIES TO INNOVATE

Ecoregional portfolios are solution sets. In some highly altered ecoregions there are not many alternatives. In more intact landscapes, there are potentially many. Using alternative risk scenarios for multiple goal setting results in several solutions. There is room for figuring out how to best portray and implement multiple solutions while keeping track of progress, and maintaining focus on a set of priorities, while presenting multiple portfolios as solution sets.

We need to better integrate marine, freshwater and terrestrial targets while maintaining the ecological integrity and meaningful goals set within the different ecoregional frameworks. A great need which has lacked focus and development has been designing ecoregional portfolios using design goals to create and maintain functional areas of biodiversity significance and landscapes within ecoregions. Integrating the needs of targets for connectivity, natural disturbance regimes, environmental heterogeneity and other landscape processes and patterns has been lacking in most ecoregional portfolios. Many conservation planners suggest that design goals are a second phase akin to site conservation area planning, and require more detailed information and assessments. This may be true, but there is room for initiating the process at the initial portfolio design state. In addition, there is a need to develop restoration portfolios in ecoregions that are highly altered where restoration is the only option for meeting goals for many targets.

CASE STUDIES

- Scenario Building in the Utah High Plateaus Ecoregion. Six potential portfolios were produced using three sets of conservation goals and two cost surfaces. These scenarios were then integrated into a final portfolio.

- Using SITES 1.0 and expert review to create a portfolio of sites for the Southern Rocky Mountains Ecoregion. This case study details the use of SITES from deriving the data necessary for input to the final selection of areas of biodiversity significance using expert workshops.

- Automated Integration of Aquatic and Terrestrial Conservation Areas in Conservation Planning: A New Method. This new approach is called vertical integration, which allows planners to analyze aquatic and terrestrial targets simultaneously by using separate layers of assessment units, crafted to match the natural boundaries of the targets being assessed, with suitability indices incorporating impacts specific to those targets. This approach has been piloted in the Pacific Northwest Coast and the Alaska-Yukon Arctic bioregions.

- Priority Sites and Spatial Variability for the Carolinian Marine Ecoregional Assessment. Marxan automated site selection algorithm was employed to enable a dynamic decision support system (DSS) using target data and a suitability index derived from 11 indicators of anthropogenic threat to the system and its targets.

- Establishing connectivity in the Southwest Amazon A model was used to estimate the cost of migration between existing and potential priority areas in the Southwest Amazon ecoregion. This cost surface was used to establish connectivity among priority areas.

- The final biodiversity vision for the Southwest Amazon. This case study presents the finished biodiversity vision for the SW Amazon ecoregion and outlines implementation considerations.

Further examples of Ecoregional Assessments using software tools for portfolio design:

Some of the first assessments to use SITES:
- Northern Gulf Coast (80) - http://www.conserveonline.org/2001/02/b/gulf
- Middle Rockies - Blue Mountains (8) - http://www.conserveonline.org/2002/05/b/ERP_with_appendices

Some of the most recent assessments to use SITES:
- Willamette Valley - Puget Trough - Georgia Basin (2) - http://www.conserveonline.org/2004/06/g/WPG_Ecoregional_Assessment
- Apache Highlands (22) - http://www.conserveonline.org/2004/04/t/Apache_Highlands_Report

Assessments completed using SPOT
- Selva Maya Ecoregional Assessment—ongoing as of summer 2005
- Utah High Plateaus—ongoing as of summer 2005 (see case study above)

Assessments completed using MARXAN
- Greater Caribbean Basin Ecoregional Assessment – draft methods available

Assessments completed using EPAT
- Federated States of Micronesia - http://conserveonline.org/docs/2004/03/MicroPg1-47_main.pdf
- Edwards Plateau- http://conserveonline.org/docs/2005/08/Edwards%20Plateau%20Biodiversity%20and%20Conservation%20Assessment.pdf

Further examples of Ecoregional Assessments with integrated portfolios:

Assessments that integrate terrestrial and freshwater portfolios
- Apache Highlands- http://conserveonline.org/docs/2004/04/Apache_Highlands_Report.pdf
- Southern Rockies - http://conserveonline.org/docs/2002/02/SRMreport.pdf
- Great Lakes- http://conserveonline.org/docs/2005/11/Aqua_Vol1_final_e-version.pdf and http://conserveonline.org/docs/2005/11/Terr_Vol1_final_e-version.pdf
- Congo River Basin Assessment

Assessments that integrate terrestrial, freshwater and marine
- Willamette Valley- Puget Trough-Georgia Basin- http://conserveonline.org/docs/2004/06/WPG_Ecoregional_Assessment.pdf
- Cook Inlet- http://conserveonline.org/docs/2004/09/Cook_Inlet_Ecoregional_Assessment.pdf
- Chesapeake Lowlands - http://conserveonline.org/docs/2005/03/CBYplan.pdf

Further examples of Marine or Freshwater portfolios:

Marine
- Northern Gulf - http://conserveonline.org/docs/2001/02/gulf.pdf
- Bering Sea - http://conserveonline.org/docs/2004/04/Ecoregion-Based_Conservation_in_the_Bering_Sea.pdf

Freshwater
- Upper Mississippi River Basin - http://conserveonline.org/docs/2003/08/UMRB_report.pdf
- Southeast Assessment (Tennessee/Cumberland, Mobile, Mississippi Embayment, Mid-Atlantic) - http://conserveonline.org/docs/2003/08/se_biodiv_assess.pdf

TOOLS

SPOT- SPOT: The Spatial Portfolio Optimization Tool by Dan Shoutis (2003) is a technical document on the tool. A general power point presentation is available here. Contact Ecoregional Assessment data manager for technical resources (programming documentation) at era@tnc.org.

MARXAN web site: http://www.ecology.uq.edu.au/index.html?page=20882

The EPAT Draft Users' Guide can be viewed here.

RESOURCES

Websites

Sites: An Analytical Toolbox for Ecoregional Conservation Planning. The University of California at Santa Barbara has a website available at: http://www.biogeog.ucsb.edu/projects/tnc/toolbox.html

A Practical conservation tool review from the Pacific North America Regional office, with a description on **Sites** is available at: http://conserveonline.org/2004/08/p/CPT_final_7-04_32_pp (January, 2003)

Publications

Abell, R.M., M. Thieme, et al. (2002). A sourcebook for conducting biological assessments and developing biodiversity visions for ecoregion conservation. Volume II: Freshwater ecoregions. Washington, DC, USA, World Wildlife Fund.

Andelman, S. A., I. Ball, and D. Stomms. 1999. Sites v1.0: An Analytical Toolbox for Designing Ecoregional Conservation Portfolios. Arlington (VA): The Nature Conservancy. (SITES)

Ball, I. R. and H. P. Possingham, (2000) MARXAN (V1.8.2): Marine Reserve Design Using Spatially Explicit Annealing, a Manual (MARXAN)

Cowling et al. 2003. The expert or the algorithm?—comparison of priority conservation areas in the Cape Floristic Region identified by park managers and reserve selection software. Biological Conservation, 112, 147-167.

Dinerstein, E., G. Powell, et al. (2000). A workbook for conducting biological assessments and developing biodiversity visions for ecoregion-based conservation. Washington, D.C., USA, Conservation Science Program, World Wildlife Fund.

Eardley, K. A. (1999) - A Foundation for Conservation in the Riverina Bioregion. Unpublished Report, NSW National Parks and Wildlife Service. – (C-Plan)

Ferrier, S. , R.L. Pressey, T.W. Barrett,2000. A new predictor of the irreplaceability of areas for achieving a conservation goal, its application to real-world planning ,and research agenda for further refinement. Biological Conservation 93,303–326. (C-Plan)

Margules, C.R. and R.L. Pressey, (2000). Systematic conservation planning. Nature 405, pp. 243-253.

Meir, E., S.J. Andelman, et al. (2004). “Does conservation planning matter in a dynamic and uncertain world?” Ecology Letters 7: 615-622.

Possingham, H.P., I.R. Ball and S. Andelman (2000) Mathematical methods for identifying representative reserve networks. In: S. Ferson and M. Burgman (eds) Quantitative methods for conservation biology. Springer-Verlag, New York, pp. 291-305. (MARXAN)

Pressey, R.L., H.P Possingham, and C.R. Margules, 1996b. Optimality in reserve selection algorithms: When does it matter and how much? Biological Conservation. 76: 259-267.

Pressey, R.L., I.R. Johnson, and P.D. Wilson, 1994. Shades of irreplaceability: Towards a measure of the contribution of sites to a reservation goal. Biodiversity and Conservation. 3: 242-262.

Pressey, R.L., S. Ferrier, C.D. Hutchinson, D.P. Sivertsen, and G. Manion, 1995. Planning for negotiation: Using an interactive geographic information system to explore alternative protected area networks. In D.A. Saunders, J.L. Craig & E.M.

Mattiske (eds). Nature conservation 4 - The role of networks. Surrey Beatty and Sons: Sydney.

TNC et al., (2004). A Blueprint For Conserving The Biodiversity Of The Federated States Of Micronesia. The Nature Conservancy, Arlington, VA. (EPAT)