Ecological Processes at the Ecoregional Scale: Considerations for Portfolio Design

Guidelines for Ecoregional Team Leaders from the Stewardship Expert Team

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The Nature Conservancy®

Introduction and Purpose

Ecological processes such as fire, herbivory, hydrology, nutrient cycling, and plant and animal dispersal sustain all natural systems and their biodiversity components. These ecological processes are highly variable and extremely complex, and humans have influenced them to a greater or lesser extent at virtually all our conservation sites. They occur at many different temporal and spatial scales, from small forest gap-dynamics to river flooding and landscape fires.

The objective of TNC's ecoregion-based conservation in general, and portfolio design specifically, is to identify and protect the suite of sites that captures all species and natural communities in an ecoregion. One of the most important concepts in this new approach is that the portfolio of sites and the conservation targets within them must be viable over the long term. *The single most important aspect of long-term viability for our conservation targets is the intactness or restorability of ecological processes and the resulting landscape patterns.* Thus, to be successful in our conservation goals we must evaluate ecological processes during <u>all phases</u> of ecoregion-based conservation. Some parts of our current approach pay explicit attention to these ecological processes -- such as multi-site threat assessment and site conservation planning. We have addressed these concepts only indirectly during portfolio design.

The purpose of these guidelines is to provide ecoregional team leaders with some basic suggestions for incorporating ecological processes into portfolio design. Teams often use EO ranks to determine viability of target occurrences. However, this information should only be considered a starting place. EO ranks are not rigorous measures of occurrence viability because they emphasize current condition. Long-term viability is much more than current condition. For example, vulnerability of an occurrence to threats and the presence (or absence) of those threats will influence long-term persistence. In addition, EO rank does not address the broader concept of viability where many targets occur together, where intact processes must be viewed from a systems perspective, or where conservation targets consist of surrogates or other coarse-level information (e.g., broad habitat types, associated groups of communities, assemblages of species). The majority of portfolio sites will need to protect multiple targets including rare species, combinations of rare and common community types, or combinations of species and communities.

It also should be noted that the guidelines and criteria outlined in the following sections are target dependent. For example, you obviously don't need to consider fire at a site if it does not sustain the conservation targets that site will protect. The final choices for site size, configuration, and location in relation to ecological processes will depend on the conservation targets at the site. Where there are many conservation targets, the dominant ecological processes will help determine similar groupings for evaluation (e.g., lump fire-dependent community types, lump aquatic species, etc).

Although many of the recommendations within this document are intuitive, we believe that explicit consideration of them in site selection/portfolio design will insure a better portfolio. In addition to the criteria themselves, we highlight data sources and suggestions for efficiently incorporating these concepts where possible. Consideration of ecological processes during site selection is critical, especially for ecoregions where the majority of sites are not known. As an organization we are just beginning to systematically incorporate ecological processes at the site level. We must now expand that process-based thinking to the ecoregional scale.

Fire

A surprisingly large number of conservation targets require fire. Fire has been such a significant evolutionary force that species and communities have come to depend on, and in some cases facilitate, its spread. In portfolio site selection, it is important to consider the dependence of conservation targets on fire and the role fire plays in creating or maintaining their habitats.

The degree to which fire maintains natural systems varies significantly. *Fire-maintained* ecosystems are those where fire is essential. It is not a disturbance or a succession-initiating process, but rather a forcing function as vital as rainfall. Exclude fire, or simply alter the fire regime that characterizes such an ecosystem, and habitats disappear and species are lost. A typical example is longleaf pine ecosystems of the southeastern US. Other conservation targets are *fire-influenced*. In these situations fire is a disturbance that affects community structure and species composition by creating successional habitats. Examples of this type of system include a variety of mixed hardwood forests, both temperate and tropical. *Fire-independent* ecosystems are wholly unaffected by fire, and these are relatively uncommon. Examples usually occur in excessively humid, dry, or cold environments making them either too wet to burn, or not productive enough to provide a continuity of fuels.

Historically, fire was a landscape-level process. During very dry years fires likely impacted entire ecoregions. Fires would burn across landscapes impeded only by natural fuel breaks and moisture. Today, however, fire rarely operates at such a scale. Aggressive fire suppression and prevention often are cited as causing the loss of fire-maintained habitats, but in most ecoregions the loss of fire as an ecological process has been due to landscape fragmentation. Farms, fields, roads, urban developments, and land use activities limit fire's spread. Tiny remnants of flammable vegetation are unlikely to experience ignition or ignitions frequently enough to prevent detrimental changes in ecosystem structure, function, or composition. In many fire-prone environments, fire regimes also have been altered through the introduction of non-native species that change fuel characteristics and create conditions that promote the invasive species at the expense of native species.

Because fire no longer operates at the scale of regional landscapes, and because there are very few places where free-ranging wildfires can be tolerated, fires have to be managed. To preserve viable examples of many of our conservation targets, we must now design fire regimes that will meet their needs and allow them to persist. We also must apply those fires in a carefully controlled manner. For some targets, we may have to manage fires in more than one ecoregion. For example, the Kirkland's warbler nests in fire-maintained jack pine forests of the upper Midwest, but overwinters in fire-maintained Caribbean pinelands in the Bahamas. Thus, it is to our great advantage to consider fire and the potential to implement fire management when selecting portfolio sites.

Considerations for site selection:

1) FIRE-DEPENDENT TARGET(S) -- Make an assessment of the ecological need for fire and to what extent the targets depend on fire. If targets depend on fire, assess whether fire management is feasible. The criteria below can help determine its feasibility for a site. Select sites where fire is feasible when fire-dependent targets are present.

2) MINIMUM AREA -- Multiple targets at small remnant sites may have different prescribed fire goals that are incompatible with one another. Habitat requirements for different suites of species may be mutually exclusive. They may require similar vegetation types exposed to slightly different fire regimes or different stages of development and time since fire. Managing for all, or even several, in a small remnant landscape may not be possible. If there are a diversity of fire goals, sites must be large enough to accommodate these multiple objectives.

3) INTACT LANDSCAPE MATRIX -- Extensive fire-maintained ecosystems historically formed mosaics of easily ignited, highly flammable, and continuous fuels that allowed fires to either maintain or influence many small-patch community types imbedded within the matrix. Without an intact matrix, maintaining uncommon, small-patch communities may not be possible. Fire-maintained small-patch communities ideally should be captured at sites where they are embedded within unfragmented intact matrix.

4) NON-NATIVE SPECIES -- Determine if non-natives control the fire regime. If they do, it may not be possible to maintain the structural and functional integrity of the conservation targets.

5) DISTANCE FROM HUMAN SETTLEMENT -- Burning may be prohibited, become prohibited, or become so constrained that ecologically appropriate fire regimes would be impossible at sites near human settlements. In considering sites of equal conservation value, priority should be given to those most distant from areas likely to experience urban encroachment or come under air quality restrictions.

6) SUPPORTIVE LAWS & LOCAL ORDINANCES OR EXISTING FIRE MANAGEMENT -- The ability to burn and the manner under which it can be done are controlled by state law and local ordinances. These vary widely. Within an ecoregion, focus on areas with a long history of burning and local acceptance. New sites adjacent to public lands already under fire management are more feasible to manage with fire than areas where the practice is not common.

7) SMOKE BUFFERS -- Look for sites with buffer areas that will facilitate burning and limit smoke impacts. These buffers should be included in site design.

8) POTENTIAL RESOURCES, TECHNICAL SKILL, & LONG-TERM COMMITMENT -- Fire management is expensive, requires a high level of technical skill, and demands a long-term commitment. TNC has been successful in implementing fire management programs in some very difficult settings, but these programs are expensive. Sites with fire-dependent targets must have at least the potential for the financial resources, technical skills, and long-term commitment necessary for successful management of these targets. It is also important to consider which sites will benefit most from our fire management dollars, and whether the desired conservation outcome justifies the expense.

General points:

- Substitutions for fire are limited. Some management techniques can be used in concert with fire to restore or maintain certain habitats, but in most fire-maintained systems, cutting, mowing, chopping, or grazing do not mimic the effects of fire in removing humus, exposing a mineral soil seed bed, releasing nutrients, and stimulating flowering and seed germination.

- The Nature Conservancy is not in the business of recreating historic landscapes but rather preserving elements of biodiversity. Conservation goals should focus on the life histories and dynamics of our conservation targets not on restoring historical fire regimes in landscapes where they no longer can exist.

Data sources:

- In-house expertise. TNC has a network of skilled prescribed fire practitioners familiar with burning in most ecoregions. This network is coordinated through TNC's Fire Management & Research Program in Tallahassee, FL.

- Other expertise. In ecoregions where we lack expertise, there are federal agency fire ecologists and fire managers, and in some cases, state or private practitioners who can provide input. National fire management programs of the US Fish & Wildlife Service, US National Park Service, US Bureau of Land Management, US Bureau of Indian Affairs, and the US Forest Service are located at the National Interagency Fire Center in Boise, ID. Specific contacts can be recommended through TNC's Fire Management & Research Program.

- Air quality standards. States are required to develop rules regarding standards set forth in the Clean Air Act. New standards for particulate matter (i.e., smoke) have recently been established. It will be several years before non-compliance areas are identified. Once they are, burning may be restricted in airsheds that do not meet standards. Planners should be aware that some counties and municipalities may restrict burning beyond what is required at the state level. Paula Seamon, assistant director of TNC's Fire Program, keeps abreast of air quality issues and potential restrictions.

- Fire effects information. The US Forest Service maintains a computerized compendium of abstracts and literature on fire effects and fire ecology encompassing 878 plants species, 101 animal species, 27 plant communities, and 25,500 literature citations: *http://www.fs.fed.us/database/feis*.

- Fire ecology literature. TNC's Fire Management & Research Program, located at Tall Timbers Research Station, has access to the Station's extensive fire library, which includes the E.V. Komarek Fire Ecology Database containing over 10,000 citations to books, journal articles, conference proceedings, and government documents related to fire ecology and fire management.

- TNC fire management activities & issues. See the Fire Program's homepage: *http://www.tncfire.org*, and the Fire Program's newsletter *Rx Fire Notes*.

For more information contact Ron Myers (ronmyers@earthlink.net, 850-668-0827) or Paula Seamon (rxfire@tallynet.com, 850-668-0827) at TNC's Fire Management Program.

Grazing

Herbivory is the ecological process that transfers energy from primary producers (plants) to higher trophic levels. Countless physical and bio-chemical changes are associated with these energy transfers. Herbivores interact with soils, plants, and other animals to produce unique successional patterns at multiple scales. These spatial and temporal habitat mosaics are the adaptive background within which species and communities remain viable or are extinguished. Although herbivores of all sizes (nematodes to elephants) participate in the ecological process, we generally use the term *grazing* to refer to terrestrial herbivory by species in the goose to bison size range. Grazing is primarily used to describe foraging on herbs as opposed to browsing (foraging on woody plants). In either case, humans have played a significant role as competitors, predators, and managers of grazing and browsing animals for many thousands of years. Specifically, this section deals with issues to consider in portfolio design, particularly ungulate grazing in grassland and woodland systems.

Ungulate grazing patterns and resulting consequences for biodiversity are determined by the interactions of four factors: (1) the individual grazer, (2) the local and regional environment, (3) the conservation targets, and (4) the actions of the manager. An ungulate species has a characteristic group of plants upon which it forages, but diet preferences can range widely depending on what is available. In addition to the direct impact on the plants, many other physical and biological changes occur as a result of grazing. These impacts are not uniformly distributed because of the way grazers select habitat at the landscape and regional scale. In addition, the effects of grazing impacts will vary dramatically for different conservation targets. Conservation targets may require, or be negatively impacted by grazing. They may occur in habitats selected for, or avoided by grazers. Finally, human induced changes in the landscape and associated management activities may be the strongest determinants of grazing impacts. Livestock, if present, and semi-domestic and wild ungulates need to be managed to maintain conservation targets at portfolio sites. Exceptions to this rule are increasingly rare.

Sound grazing management for food and fiber production requires a combination of art and science. This will also be true to meet conservation objectives. As with prescribed burning, the more emphasis that is placed on grazing to achieve a precise biological objective, the less it is an ecological process and the more it is a management tool. In addition, most portfolio sites (and the regional matrix they are embedded within) are significantly modified from historic conditions. Thus, grazing management should be assessed as to its potential to accomplish the goals at the site rather than for its potential to simulate pristine conditions. Regardless, herbivory will remain an important ecological process, and grazing a powerful but relatively imprecise conservation tool.

Considerations for site selection:

1) GRAZING-ADAPTED TARGETS & EVOLUTIONARY HISTORY -- It is most important to consider grazing for conservation targets that are well adapted to herbivory. Generally, species that are adapted for grazing will make use of different successional habitats in a dynamic mosaic rather than being restricted to the same places on the landscape. However, some species may be associated with unique and localized habitats that are neither adapted for grazing nor spatially dynamic. These areas would need to be excluded from grazing, grazed lightly, infrequently, or during a time of the year when grazing is tolerated. Similarly, if native plant communities have a long evolutionary history of grazing they will require grazing by a similar ungulate to maintain their structure and function. Matrix and large patch plant communities will tend to be most robust in the presence of grazing, while some small patch communities within the same landscape may be less tolerant of grazing due to specialized conditions. Native plant communities without a long history of grazing may reorganize their structure and function in response to grazing in ways that are undesirable. Select porfolio sites that are in alignment as much as possible with the region's evolutionary grazing history and the grazing requirements of the conservation targets. That is, make sure appropriate grazing management is occurring, or is possible to implement, at sites where targets depend on herbivory. Conversely, make sure that grazing is not occurring, can be terminated, or at least that inappropriate grazing practices can be changed where conservation targets don't depend on herbivory.

2) MOISTURE REGIME -- Plant communities with a long evolutionary history of grazing range from mesic to arid. In mesic plant communities with a long evolutionary history of grazing, individuals compete for light and nitrogen. Selective grazing on the most competitive species reduces their canopy dominance and allows a more diverse groups of plants to be maintained. Grazing also increases the rate of nitrogen cycling within plant communities and alters the spatial distribution of this limiting plant nutrient. Again, a more dynamic nutrient supply prevents

dominance by a few species. In arid areas with a long evolutionary history of grazing, plant adaptations to water stress and grazing converge and tend to reinforce each other. In the shortgrass prairie for example, matrix species have short-stature, high leaf area-to-volume, non-elevated meristematic tissue, and vegetative (rhizomes/stolons) reproduction. These characteristics are good plant strategies for both tolerating water stress and grazing. Mesic plant communities without a history of grazing are characterized by species adapted to unique overstory or understory light conditions. These plants do not have adaptations to grazing, but instead respond to canopy gaps resulting from wind, insect, and age losses. Canopy gaps and nutrient patches resulting from grazing in these situations form atypical habitats that can be colonized readily by weedy native and exotic plants. Arid communities without a history of grazing are composed of species whose adaptations for water stress do not necessarily confer grazing tolerance. As with mesic plant communities lacking an evolutionary history of grazing, the risk of exotic species invasion is high under arid conditions. Portfolio sites across the moisture regime of an ecoregion will be needed to capture the range of expressions in plant communities. Grazing management may or may not be appropriate across this moisture regime. If appropriate, stocking rates for grazing should be directly proportional to average annual precipitation at a site.

3) SCALE -- Grazing management is most effective at producing desired changes at the landscape scale. Grazing does affect smaller scale phenomenon such as within-community and between-species light, moisture, and nutrient availability, but management influence is relatively low in native rangeland situations at this finer scale. Selection of larger portfolio sites will allow for more flexible grazing management, and have the potential to accommodate a variety of species and community requirements.

4) NON-NATIVE SPECIES -- Threats from exotic species increase when grazing occurs on areas where it was not a significant part of the evolutionary history. Large ungulates transport seeds and can create beneficial seedbed and seedling conditions for non-native plants. Grazing has been proposed as a tool for controlling some exotic species. As a rule, this is not effective due to the complexity of native plant communities and the poor control of animal foraging. However, grazing may be a good short-term treatment in combination with other tools such as fire, chemical, or mechanical control of an exotic. Grazing will be a poor stewardship choice on small sites within an agricultural or urban matrix that fosters high levels of exotic species. This will be especially true if the grazing animals are regularly moved between portfolio sites and the surrounding disturbed matrix.

5) COMMUNITY AND PROGRAM CAPACITY -- Since sound grazing management is a combination of science and art that must be adapted to local conditions, special considerations should be given to insuring the continuity of staff and program efforts. It is becoming increasingly difficult to recruit qualified personnel to run grazing management programs in some areas. Sites that require grazing management must have in place, or have the potential to have in place, qualified staff, adequate resources, and long-term commitment.

General points:

- If grazing is to be used to achieve conservation objectives at portfolio sites the four principles of grazing management must be applied. They are:
    1. the species of grazing animal(s) is appropriate,
    2. the number of grazing animals is appropriate,
    3. the distribution of grazing animals is appropriate,
    4. grazing occurs at the appropriate time.

"Appropriateness" is determined by the conservation targets, forage resources, and the *manager's objectives*.

Data sources:

- The Nature Conservancy. 1995. Biological Management - Grazing. Pages 3.1 - 3.13 In: *Tools for intelligent tinkering: a steward's handbook*. Available from the National Stewardship Department, Home Office.

- Non-TNC staff resources:

    Natural Resources Conservation Service (NRCS) district technical support center staff.
    Cooperative USDA-Land Grant University Agricultural Extension Service office staff.

Bureau of Land Management district office staff.
Forest Service district office staff.
State land management agency staff.

- Web sites:

  Center for Grassland Studies: *http://ianrwww.unl.edu/ianr/cgs*. General information on a variety of issues related to grassland management and the role of grasslands as a natural resource and conservation measure.

  Konza Prairie LTER Web Server: *http://climate.konza.ksu.edu*. Information and data related to research conducted at the Konza LTER site. Some spatial data available.

  National Resources Inventory: *http://www.nhq.nrcs.usda.gov/NRI*. Statistically based sample of land use and natural resource conditions and trends on U.S. non-federal lands. Statistical and spatial data available.

  Rangeland Watershed Program Fact Sheets: *http://agronomy.ucdavis.edu/CALRNG/htoc.htm*. Information on issues such as rangeland water quality, rangeland watershed management, riparian pastures, and grazing effects on riparian areas.

  National Agricultural Library: *http://www.nal.usda.gov.*

  National Agricultural Statistics Service: *http://www.usda.gov/nass*. Includes data on crops, livestock, economics; historic data; and data on land use and ownership from the census of agriculture. Statistical and spatial data available.

  USDA Economics and Statistics System: *http://usda.mannlib.cornell.edu:80/usda*. Nearly 300 reports and datasets from the economics agencies of USDA.

For further informatin contact Al Steuter, Director of Science and Stewardship for Nebraska, at natcon03@nol.org, 402-387-1061.

Invasive Species

Invasive species degrade biodiversity or have the potential to do so in most of the areas where we work. Invasive species are non-native weeds, pest animals, and diseases that move into natural areas and interfere with long-term survival of conservation targets. There are a few native invasive species that spread into and dominate new habitats, driving out other native species of importance. For example, the native grass *Phragmites australis* is invasive in many wetlands in the eastern U.S. Disturbed and fragmented sites are most susceptible to invasion, but even intact protected areas subject to little or no human disturbance may be invaded and degraded over time.

In portfolio design it is important to determine the level of threat from invasive species and whether it will be possible to control them. We rarely if ever have the resources to control all non-native species and in most areas the majority are not invasive. Determining which ones threaten the viability of our conservation targets, and setting priorities among them is both important and challenging. It requires information about how the overall ecological system functions and which species interfere or are likely to do so as their numbers increase.

Negative effects of invasive species influence ecological systems at many levels and in many ways. At the ecosystem level invasive species alter processes such as nutrient cycling, fire frequency, or streamflow. For example, non-native cheat grass sharply increases fire frequencies across vast areas of intermountain shrublands and grasslands. At the community level invasive species alter the structure or physiognomy of plant communities. The invasive punk tree, *Melaleuca quinquenervia*, converts herbaceous marsh to forested swamp, and goats can convert native shrublands into species-poor grasslands or unvegetated badlands. At the species level invasives significantly reduce or eliminate native species populations. The chestnut blight eliminated American chestnuts from eastern forests and starlings reduce numbers of native birds by competing for food and nest sites. Finally, at the genetic level invasives hybridize with related native species and even have the potential to eliminate individuals with purely native genes. *Spartina alterniflora*, native to the Atlantic and Gulf coasts, invaded Pacific estuaries where it hybridized with native *Spartina foliosa*. Now, pure strains of *S. foliosa* are impossible to find in some Pacific marshes.

To preserve viable examples of many of our conservation targets we must select sites where we can prevent the establishment of invasive species or control those that are present, keeping their impacts below an acceptable threshold. Prevention and early detection and elimination are most effective for addressing these issues. Therefore, sites free of invasive species should be favored where possible. Even among uninvaded sites, some will be easier to defend than others. For example, small, fragmented areas with high edge-to-area ratios are usually more vulnerable than larger, more intact sites. On the other hand, some systems may be better protected if they are isolated from similar invaded habitats, and perhaps surrounded by developed landscapes hostile to the invader. For example, invasive fishes have been unable to reach some perennial headwaters in the southwest because of impassable lower stretches that are dry, carry flood flows, or have dams.

In many ecoregions, all or most potential sites have already been invaded. In these cases it is preferable to choose sites where control or containment is most feasible. Conditions that favor control and restoration vary with the type of invader (e.g., invasive plant versus aquatic animal), the system invaded, the conservation targets, and the management goals (e.g., fire or grazing management programs can help control some invasives but may spread others). Thus it is very important to consider invasive species and the potential to control them when selecting portfolio sites.

Considerations for site selection:

1) INVASIVE-FREE SITES -- The best sites are those that have no or few populations of invasive species and that are unlikely to be invaded because they are surrounded by invader-free buffer areas or invasion-resistant biological communities. Where possible, select sites that are not invaded, and are not likely to be invaded.

2) SITES WHERE INVASIVES DON'T INTERFERE WITH CONSERVATION TARGETS -- Sites that are invaded already or subject to invasion in the future may be able to support viable populations of certain native species. For example, some native species compete well with invaders under certain conditions, or may grow in areas the invaders don't occupy. Some target animal species (particularly generalist vertebrates) can nest in and feed on non-native plant species. Host-specific insects and other animals that depend on certain plant species for food or reproductive

habitat are more likely to decline or disappear from invaded areas. For already invaded sites, select those where invasives don't interfere with the conservation targets.

3) SITES WHERE INVASIVES CAN BE CONTROLLED OR ELIMINATED -- Some invaded sites may be capable of supporting native species if the invaders can be controlled or even eliminated. For example, small populations of many woody shrubs can be eliminated by burning, pulling, or herbicide treatments, and some invasive species populations can be sharply reduced by biological control. In contrast, some species are extremely difficult if not impossible to control with methods available today. These include non-native aquatic invertebrates especially zebra mussels, non-native fish, and non-native aquatic plant species. It is important to remember that all control methods entail risks to the organisms we seek to protect as does failing to control the invaders. Where sites have invasives that interfere with the conservation targets, select only those where invasives can be controlled or eliminated with active management.

4) SITES WITH INTACT NATURAL DISTURBANCE REGIMES OR MINIMUM HUMAN DISTURBANCE -- Disturbance, and human caused disturbance in particular, often promotes invasions. In general, sites subjected to a minimum of human-caused disturbance are less likely to be invaded in the future. On the other hand, some systems and communities depend on and cannot persist without natural disturbances such as floods, fires, or hurricanes. Select sites where natural disturbance regimes are as intact as possible and where human disturbance is minimal.

General points:

- Preference should be given to sites with: (1) no invasive species and invasion-free buffer areas, (2) no invasive species and minimal invasion in buffer areas, (3) few invasive species and minimal invasion in buffer areas, (4) few invasive species and heavy invasion in buffer areas, and (5) invasive species that need active control via management.

- To begin, it may be helpful to assemble a list of the invasive species that are most damaging in the ecoregion before engaging in the site selection process. This can be done by consulting natural area weed and pest lists and consulting with stewards and other land managers in the ecoregion (see next section).

- Be sure to consider species that may invade from adjacent sites or regions in coming years and decades (e.g., zebra mussels are not yet in the Missouri River drainage but are likely to invade). Focus on prevention and early detection of weeds and pests. This requires gathering information and location data about species most likely to invade and continued vigilance at all sites. The best predictor of whether a new species will be invasive is whether it is invasive elsewhere outside its native range.

Data sources:

- Lists of invasive weeds of natural areas are available for various regions, states, preserves, and national parks. Stewards will know weeds in their areas, and also may be aware of problem species that have not yet been listed. TNC's Wildland Weeds Program has copies of weed lists produced by the agencies listed below plus several others, and produces a nationwide list of all non-native weeds reported on TNC preserves.

    California - California Exotic Pest Plant Council, contact Sally Davis at *sallydavis@aol.com* or visit *www.igc.apc.org/ceppc.*

    Florida - Florida Exotic Pest Plant Council, contact Amy Ferriter at *amy.ferriter@sfwmd.gov* or visit *http://www.fleppc.org*.

    Illinois and surrounding states - Illinois Natural Areas Commission - Vegetation Management Guidelines.

    New York - NY Natural Heritage Program, contact Steve Young at *syoung@tnc.org.*

    Oregon/Washington - Pacific Northwest Exotic Pest Plant Council, contact Sarah Reichard at *reichard@u.washington.edu*.

Rhode Island - Rhode Island Wild Plant Society, (401) 949-0195.

Tennessee - Tennessee Exotic Pest Plant Council, *www.webriver.com/tn-eppc*.

Virginia - Virginia Native Plant Society, P.O. Box 844, Annandale, VA 22003.

- Several TNC field offices have developed expertise in controlling one or more invasive animals but we have no centralized source of information on invasive animal control at this time. There are university scientists and state biologists at institutions and agencies around the country and around the world interested in the biology and control of invasive animals and/or plants. Many are willing to analyze threats by invasive species and/or offer control suggestions. If you need help locating someone with expertise on invasive species (particularly weeds) contact the Wildland Weeds Program.

- To determine which plant species are most threatening in your area you also may consult the Handbook for Ranking Exotic Plants for Management and Control (Hiebert and Stubbendieck 1993) or TNC's Site Weed Management Plan Template, Section B -- "How priorities are set" (available on TNC's Wildland Weeds homepage or hard copies from the Wildland Weeds Program).

- Invasive species literature: TNC's Wildland Weeds Management & Research Program, located at the University of California, Davis, has access to the University's excellent library and reference databases. The program also maintains extensive files on over 250 invasive plant species, control methods, and a contacts database that includes experts on weed ecology and control from across the U.S. and Canada.

- For TNC weed management information see the Weed Program's homepage: *http://tncweeds.ucdavis.edu.*

For more information contact John Randall (jarandall@ucdavis.edu, 530-754-8890) or Barry Meyers-Rice, (bazza@ucdavis.edu, 530-754 8891) at TNC's Wildland Weeds Program.

Hydrology

Protecting or restoring natural hydrologic regimes and water chemistry is fundamental to conserving aquatic, riparian, and wetland species and communities. Freshwater conservation efforts within The Nature Conservancy are guided by the "Natural Regime Paradigm" (Richter *et al*. 1997, Poff *et al*. 1997). This paradigm asserts that conserving the full range of natural variation of environmental processes is critical to sustaining the native biodiversity and ecological integrity of freshwater ecosystems. The implication of this paradigm for applied conservation efforts is that natural environmental conditions and their variability (including streamflows, water chemistry, erosion and sedimentation, etc.) need to be protected or restored to maintain the ecological and evolutionary potential of these systems.

Full restoration of natural environmental regimes may often be unlikely or impossible. Even partial restoration is difficult, time-consuming, and expensive. Thus, it is critically important that we assess hydrologic process integrity during the earliest phases of ecoregional planning. At this time we cannot provide much guidance about the degree of hydrologic restoration or natural regime protection necessary to ensure long-term viability of freshwater targets. However, we do know that hydrologic integrity and water chemistry are an essential aspect of viability for freshwater biota, and that it is important to select sites with least-altered environmental regimes. Fortunately, numerous environmental data sets at various levels of detail or resolution are available for analyzing freshwater site conditions within the US. Some of the analyses described here are equally applicable outside the US, but are limited by data availability.

Considerations for site selection:

1) FLOW REGIME -- Healthy freshwater ecosystems evolved with, and are dependent upon, naturally varying hydrologic conditions. When the magnitude, timing, frequency, duration, or rates of change in hydrologic conditions are modified by human activities, many freshwater species and communities are jeopardized. More intensively developed or cultivated watersheds experience the greatest degree of hydrologic alteration. Land use/land cover and the presence of dams and surface water diversions are useful 'first impression' indicators of flow integrity (see the chapter on Landscape Patterns for more guidance on use of land use/land cover data). Select sites whose flow regimes are least altered.

2) WATER CHEMISTRY -- Changes in the natural water chemistry regimes of a river or lake can impact native biota through both chronic and toxic effects. Problems with water quality can be expected in more intensively developed or cultivated watersheds. Again, land use/land cover data are a very useful simple indicator of potential water quality problems. The presence of point source pollutant discharges, such as municipal wastewater treatment plants and industrial polluters, is another important warning sign. Select sites whose water chemistry is least altered.

General points:

- Water chemistry and flow regime are interrelated at most sites. Examine interactions between these criteria and use ecological requirements of specific targets to help determine the relative importance of each.

- Considerable information is available to assess the hydrologic and chemical integrity of watersheds or river/stream segments. Evaluation of these data should be part of every ecoregional planning effort.

Data Sources & Analyses:

Data

- The Index of Watershed Indicators (IWI) is the first national effort to organize aquatic resource and vulnerability information and present it at a watershed scale. The Index is comprised of 15 water resource indicators, summarized at the scale of eight-digit USGS "Hydrologic Cataloguing Units" (HUCs). Table 1 provides a listing of the 15 individual indicators used in the IWI. Of these 15 indicators, we have found four to be most useful in ecoregional planning: (7) wetland loss, (11) urban runoff, (12) agricultural runoff potential, and (14) hydrologic modification. More information about the data used in deriving the Index of Watershed Indicators can be obtained from the US EPA "Surf Your Watershed" web site: *http://www.epa.gov/surf/iwi*.

Table 1. List of indicators used in US EPA's Index of Watershed Indicators

1. Assessed Rivers Meeting All Designated Uses Set in State Tribal Water Quality Standards
2. Fish and Wildlife Consumption Advisories
3. Indicators of Source Water Condition for Drinking Water Systems
4. Contaminated Sediments
5. Ambient Water Quality Data - Four Toxic Pollutants
6. Ambient Water Quality Data - Four Conventional Pollutants
7. Wetland Loss Index
8. Aquatic/Wetland Species at Risk
9. Pollutant Loads Discharged Above Permitted Limits - Toxic Pollutants
10. Pollutant Loads Discharged Above Permitted Limits - Conventional Pollutants
11. Urban Runoff Potential
12. Index of Agricultural Runoff Potential
13. Population Change
14. Hydrologic Modification Caused by Dams
15. Estuarine Pollution Susceptibility Index

- The US EPA has developed another tool called "BASINS". BASINS provides data that can be used for a variety of map-making and analysis purposes. These data are packaged as Arc/Info coverages, and are distributed on CD-ROM. The BASINS data for each EPA region can be obtained free upon request: 800-490-9198. For a useful summary of the BASINS data for TNC planning teams contact Brian Richter at *brichter@theriver.com*.

- Larry Master, TNC's Chief Zoologist, is leading an effort to compile historic and current distributional information for freshwater animal species on a watershed (HUC) basis. For certain animal groups such as fish and mussels, we are now able to develop a measure of "biological intactness" (%) for each watershed, derived by comparing the number of current vs. historical species. This indirect measure of biological integrity may guide ecoregional planners to watersheds that still retain much of their original component of native aquatic species, a potentially important measure of ecological variability and integrity. Larry Master is at ERO and can be reached via email at *lmaster@tnc.org.*

- We are continually searching for other relevant data, such as water consumption within watersheds, for use in ecoregional assessments. We will keep ecoregional planning teams apprised of any new data discoveries.

Additional analyses:

- Once potential freshwater sites have been identified for conservation attention, a more in-depth evaluation of hydrologic and chemical integrity is warranted. The Biohydrology Program of TNC has developed an "Indicators of Hydrologic Alteration" (IHA) method (Richter *et al*. 1996) and software to enable conservation practitioners to assess historic alterations or trends in hydrologic regimes. The method can be applied to any river or stream segment for which daily streamflow records (e.g., from USGS streamgage stations) are available. By characterizing hydrologic changes along a river of interest, conservation practitioners will understand hydrologic alteration (e.g., reductions in baseflows, elimination of high magnitude floods, etc.) and will be able to assess the feasibility of mitigating or correcting those alterations.

For more information contact Brian Richter (brichter@theriver.com, 520-803-0882) or David Braun (dbraun@tnc.org, 212-997-1880, ext. 24) at TNC's Freshwater Initiative and Biohydrology Program.

Landscape Characteristics: Surrogates for Ecological Processes at the Ecoregional Scale

It is often difficult to obtain direct information on ecological processes at an ecoregional scale. Broad-scale data typically are lacking or are costly to produce. Thus, it is important to identify landscape characteristics that can be easily distinguished from remotely sensed data and used to represent more specific processes like fire, hydrology, natural recruitment, and dispersal. For example, we may not know the location of invasive exotics or the distribution, frequency, and extent of natural fires, but we can select a larger site over a smaller site with the assumption that ecological integrity and processes will be more intact at the larger site. Consideration of landscape characteristics is not a substitute for other critical data and analyses discussed under previous sections, but can be used as a minimum when more specific data are not available and resources to collect such data are lacking.

The considerations outlined below are also intricately woven with concepts related to incorporating natural vegetation communities into portfolio design. For example, new EO rank specifications and viability assessment by Heritage programs for natural communities will consider landscape context, size, and condition. Thus, the criteria outlined below directly parallel those used to assess community occurrence viability because in many cases the extent of a vegetation community type or types will define site boundaries at the ecoregional scale. The criteria below can serve as surrogates for a wide array of ecological processes that affect multiple conservation targets. Additional complementary information on natural vegetation communities and portfolio design also can be found in the recommendations of the Community Goals Working Group[1].

There are three primary landscape characteristics that can be used as first-cut surrogates for ecological processes at the ecoregional scale: size, continuous natural vegetation cover, and connectivity.

Considerations for site selection:

1) SIZE -- All else being equal, larger natural areas are preferable over smaller ones. Large protected areas help combat direct habitat destruction, conversion, and loss. In addition, larger natural areas typically have more intact ecological processes and disturbance regimes, and support organisms higher up the food chain. Species populations at larger sites are often more stable making them less prone to extinction, and larger sites typically are easier to manage (e.g., burning). Finally, larger areas increase the chances that species and communities will survive stochastic natural disturbance events, or that their propagules can recolonize a site following a disturbance that removes most or all individuals. This "minimum dynamic area" is essential for long-term persistence and viability. Wherever possible, teams should estimate minimum dynamic areas for conservation targets. Consideration of size is particularly important for natural community targets that are "matrix-forming" (i.e., dominant across the landscape, naturally covering very large areas), for wide-ranging species targets, and where sites are surrounded by hostile non-natural land uses.

2) CONTINUOUS NATURAL VEGETATION COVER -- Sites that have continuous natural vegetation cover are preferable over sites where natural vegetation is dissected, fragmented, or otherwise interrupted by human uses. The assumption is that areas with continuous natural cover have more intact ecological processes and less interference from humans than sites that have non-natural cover types interspersed throughout. Such places are more likely to be free of invasive exotic species and have existing natural disturbance regimes. Wherever possible portfolio sites should have as much continuous natural cover as possible.

3) CONNECTIVITY AND LANDSCAPE CONTEXT -- A site or target occurrence also must be assessed by it's surrounding landscape context. Areas that are connected or in proximity to other natural habitat typically are preferable over isolated areas surrounded by a human-dominated matrix. Ability to move through surrounding non-protected areas will influence many ecological processes and life cycle components of conservation targets. Keep in mind that this is not necessarily equivalent to corridors. Corridors typically are narrow habitat patches that connect two isolated areas, often focused on a specific species such as a wide-ranging mammal. Connectivity refers to the ability of organisms, propagules, pollinators, prey, or other materials to be delivered to a site when needed. Connectivity can be accomplished by corridors, adjacency, proximity, or a non-hostile matrix, depending on the species and natural

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[1] Setting Conservation Goals for Ecological Communities. Ecoregional Community Goals Working Group Report. 1998. The Nature Conservancy, Arlington, VA. Contact Mark Anderson at ERO (*manderson@tnc.org*) or Craig Groves (*cgroves@tnc.org*) for more information or a copy of this document.

communities at a site. Wherever possible portfolio sites should be connected or in close proximity to other natural areas or sites. The obvious exception to this is when invasive species are the dominant threat and connectivity will increase chances of invasive colonization (e.g., Hawaii).

General points:

- The interplay and relative importance of these three factors (size, continuous vegetation, connectivity) will vary depending on the targets and goals. In general, size will be most important for dominant communities and wide-ranging species, while landscape context and proximity will be critical for "small patch" communities such as vernal pools and dispersal-dominated species such as butterflies and small mammals. Continuous cover will be most important for targets such as interior species and fire-dependent communities. Furthermore, one characteristic may compensate in some circumstances for another characteristic. For example, higher internal fragmentation may be more acceptable if size is big. Such tradeoffs should be evaluated in light of the specific ecological requirements and dominant processes that sustain the conservation targets at a particular site.

Data sources & analyses:

Below is a quick and dirty list of broad-scale data coverages available for the US. The list is by no means comprehensive. Websites are probably most useful to start. Begin by searching some of the clearinghouse sites.

- Good starting website -- *http://h2o.er.usgs.gov/nsdi/pages/nsdi004.html*
- USGS geodata -- *http://edcwww.cr.usgs.gov/doc/edchome/ndcdb/ndcdb.html*
- USEPA spatial data -- *http://www.epa.gov/docs/oppe/spatial.html*

Data

- **Land use / land cover** -- US land use / land cover maps were digitized by USGS in the mid 1970's to early 1980's at a scale of 1:250,000. USEPA converted the data into ARC/INFO format and they are available via FTP on a 250K quadrangle basis (*URL:ftp://ftp.epa.gov/pub/spdata/EPAGIRAS*). More information is available at *http://www.epa.gov/ngispgm3/nsdi/projects/lulcmeta.html*.

  GAP vegetation maps are prepared from satellite imagery (LANDSAT) and other sources. The minimum mapping unit for vegetation maps is 100 ha with a 30 meter cell size. Quality and availability varies dramatically from state to state: *http://www.gap.uidaho.edu/gap/new/States/Index.html*.

  Many agencies (e.g. USGS, USEPA) participate in the "MRLC" consortium that classifies satellite imagery (LANDSAT) into land cover classes at 30 meter resolution. Land cover maps at this scale are being created for each federal region. Some are currently available. Check *http://www.epa.gov/grd/mrlc/* for status and more information.

  NOAA uses Advanced Very-High Resolution Radiometer (AVHRR) satellite images with a 1 km cell size. The images are classified into land cover classes and made available for each continent via *ftp://edcftp.cr.usgs.gov/pub/data/glcc*.

- **Existing managed areas** -- This data includes federal and state managed areas for the lower 48 states at the 1:2,000,000 scale. For more information visit *http://www.ncgia.ucsb.edu/mad/mad.html*. Many state GAP programs also may have these data: *http://www.gap.uidaho.edu/gap*.

- **Human population** -- Census data is available through the US Census Bureau TIGER files: *http://www.census.gov/tiger*.

- **Roads & other transportation features** -- USGS has mapped roads as at a 1:100,000 scale for the entire US. They are available as digital line graphs (DLGs) on CD-ROM or via FTP: *http://edcwww.cr.usgs.gov/doc/edchome/ndcdb/ndcdb.html*.

- **Abiotic** -- USGS has produced elevation data at varying scales (1:250K, 30,15, and 7.5 minute). Digital elevation models (DEMs) are available from the following site: *ftp://edcftp.cr.usgs.gov/pub/data/DEM*.

  STATSGO (State Soil Geographic) data are digitized at a 1:250,000 scale. The soil polygons are very generalized so that up to twenty soil series types can occur in one polygon. These data are available at the following site: *http://www.ftw.nrcs.usda.gov/statsgo.html* for downloading details.

  SSURGO (Soil Survey Geographic) data are digitized from county soil series maps (1:12,000 to 1:63,360 scale). These are currently available for a selected set of counties in the US from the following site: *http://www.ftw.nrcs.usda.gov/status_data.html*.

- **Hydrology** -- Digitized USGS hydrologic cataloging units (HUCs) are available at a 1:250,000 scale. There are three nested levels of cataloging units. Visit *http://water.usgs.gov/public/GIS/huc.html* for more information. Many states have delineated finer subwatersheds and these typically are available from state geologic or water survey departments.

  USEPA has compiled data to model point and non-point source pollution in BASINS (see Hydrology section of these guidelines). Available include dam locations, industrial facilities discharge sites, gaging stations, bacteria sampling points, land use/land cover, major roads, RF1 streams, and superfund national priority list sites. Visit *http://www.epa.gov/OST/BASINS/* for more information.

General analyses

- **Basic patch statistics** -- Basic patch statistics can help describe and evaluate ecoregions or specific portions of them. They include information on patch size, number, variability, shape, and amount of core area and edge (see below). For example: size of natural forest patches; range in size of forested patches; number of urban areas. See McGarigal and Marks (1995) for highly readable information on all pattern analysis measures outlined below. Remember that "patches" can be delineated in a variety of ways: based on land cover boundaries, roadless areas, watersheds, polygons surrounding EOs, or areas delineated by abiotic characteristics (e.g., landtype associations).

- **Buffers** -- Buffer analysis examines areas surrounding a particular feature of interest. A GIS can be used to buffer points, polygons, or lines to any distance and determine important information within that buffered area. For example: amount of forest cover within a 100m circle surrounding EOs; amount of agriculture within 300m of stream corridor; range of elevational change within 1km of managed areas.

- **Proximity** -- Proximity measures and indices can be used to determine what is in the neighborhood of a particular feature of interest. For example: distance of nearest managed area to feature of interest; patch 'isolation' (combination of size and distance of like patches within a given search radius).

- **Edges** -- Edge calculations give an indication of how much and what kind of edges habitat patches of interest contain. It is easy to calculate amount of core area (as defined by specific species requirements), edge 'contrast', total edge, density of edge, and area-weighted edges (see McGarigal and Marks 1995). For example: edge to area ratio of forested blocks; amount of edge adjacent to natural cover types versus human-influenced cover types.

- **Fragmentation** -- For many potential sites it will be critical to evaluate the degree of internal fragmentation. Simple calculations can be performed that will be easy to interpret such as: density of roads and other transportation features (e.g., railroads, utility corridors), density of houses, residential development or other human structures, and percentage of area occupied by non-natural land uses or other fragmenting features (e.g., clear cuts, plantations, orchards, agricultural land, mining activities, etc). Be careful with complex fragmentation metrics that may be difficult to interpret or even meaningless in particular applications (e.g., McGarigal and Marks 1995).

- **Diversity** -- Diversity measures can be used to determine the diversity of critical variables within a patch of interest. It may be important to choose sites with the greatest EO, vegetative, and/or abiotic diversity, particularly if targets are coarse-scale surrogates. For example: diversity of EOs within grassland blocks; diversity of abiotic factors (elevation, slope, aspect, geology, soils) within forested blocks; diversity of spectral response within managed areas.

Process-specific analyses
Based on considerations outlined in previous sections, we recommend some first-step GIS-based analyses to help guide site selection where specific ecological processes dominate.

- **Fire** --
  1. Determine land use types within an x km area of site and evaluate if these land uses are generally compatible with fire management, particularly smoke management (see **Buffers**).
  2. Calculate distance of potential sites to managed areas with known fire management (see **Proximity**).
  3. Calculate distance of potential sites to nearest residential and urban development (see **Proximity**).
  4. Calculate internal fragmentation of potential sites, using features that could interfere with fire management (e.g., roads, structures, transportation features, non-natural land uses) (see **Fragmentation**).
  5. Calculate amount of edge of potential sites that is adjacent to non-natural cover types (see **Edges**).

- **Grazing** --
  1. Determine abiotic characteristics of potential sites that will influence grazing management (e.g., moisture regime, current land uses, soils, slopes, surface water distribution, etc).

- **Invasives** --
  1. Calculate internal fragmentation that could promote invasives as in Fire #4.
  2. Calculate edges as in Fire #5.
  3. If location data for invasives are available, calculate distance of potential sites to known heavily infested areas (see **Proximity**).

- **Hydrology** --
  1. Calculate proportion of natural versus non-natural land cover within potential watershed sites.
  2. Determine land use types and proportion of non-natural land cover within x m of stream segments of interest (see **Buffers**).
  3. Calculate number of dams and/or point sources of pollution within potential watershed sites.

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