National Park System Advisory Board

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Appendix B

Natural Resources Gap Analysis: Conservation Tools for National Parks System Management in a Changing World

National Park System Advisory Board

Planning Committee

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National Park System Advisory Board Planning Committee
Natural Resources Gap Analysis:
Conservation Tools for National Parks System Management in a Changing World

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Introduction – an ecologically representative system of parks

The current system of national parks consists of park units that were established independently for a variety of reasons including scenic, wildlife, other natural and cultural values. The current National Park System is neither representative nor redundant of the natural features (e.g., land cover, ecological systems, topography, elevation and species) of America. Additionally, the size, spatial distribution and ecological integrity of the landscape surrounding many park units leaves the "scenery, natural objects and wildlife" of our National Park System vulnerable to 21st century threats such as climate and land-use change (Svancara et al. 2009; Svancara 2010).

Imagine moving to a National Park System in 2016 (the centennial celebration of the creation of the National Park Service) in which individual units are valued for the ecological contribution that they make to an informal national system of conservation areas[1] (hereafter referred to as INSCA in this report), and new park units are established in part to fill gaps in that national system. This informal national system of conservation areas or INSCA consists of a variety of state, federal, and private lands and waters that are managed to at least some degree for the purpose of conserving the native species and ecosystems of the United States across their full environmental, geographical and ecological range of occurrences. Envision a conservation system that is large and connected enough for organisms to adapt and evolve to changing environmental conditions and sustain the integrity, diversity and health of the ecological and evolutionary processes and associated ecological services in the parks. Such a system would help "ensure resilience in the face of climate, land-use change and other environmental stressors" (Second Century Commission 2009). This INSCA is needed to "protect, restore and sustain the most valuable places, landscapes and freshwater and marine environments in

[1] Unlike most countries that are signatories to the Convention on Biological Diversity, the United States is not a signatory and does not have any formally recognized system of protected areas. An informal system exists and there is a geospatial database – PADUS or Protected Area Database of the United States – that contains information on this system; the database is maintained by the US Geological Survey's Gap Analysis Program (http://gapanalysis.usgs.gov/data/padus-data/). This informal system has no official recognition in terms of policy or management by any US federal government agency.

America" (National Parks Second Century Commission 2009). The National Park System is a key component of this INSCA. The challenge facing the National Park Service (NPS) as it approaches its second century is to envision and plan for what the National Park System will look like in the decades ahead; the species, geophysical features and ecological systems it will contain; where they will be located; and what relevance this system will have to the American public and the larger INSCA. The Centennial of the National Park Service could provide a forum for conversations regarding the formalization of the INSCA and the Park Service's role in that larger conservation area network.

Ecological context of The National Park System

President Roosevelt stood at the entrance of Yellowstone National Park in 1903 announcing the world's first national park to be a place where "the wild creatures of the Park are scrupulously preserved." The desire for parks to preserve wildlife has been an assumed tenet for national parks around the world. Unfortunately, an increasing body of science indicates that this tenet is unlikely to be successful if the focus of conservation remains solely inward into the parks. The existing global protected area model in which parks and other conservation areas cover a relatively small area of land is a necessary strategy for conserving the world's biodiversity (Rodriques et al. 2004), but is insufficient without a consideration of the larger landscapes and watersheds within which parks and conservation areas are imbedded. Examples around the world document species losses within parks, and link these losses to impacts beyond park boundaries (e.g., Craigie et al. 2010). Most parks are simply not large enough to maintain all the species within them (Newmark 1987, 1995) or natural processes such as fire and migration. As but one example, we now know that conservation of a long-term viable population of wolverines (*Gulo gulo*) in the lower 48 states requires trans-jurisdictional management across the high elevation National Parks and other jurisdictions that make up wolverine habitat in the Rocky Mountains (e.g., Schwartz et al. 2009; Inman et al. 2011).

Conservation areas that are surrounded by a sea of development are less likely to successfully conserve what falls within their boundaries over the long term. Svancara and colleagues (2009) assessed the ecological context and connectivity of the National Park System. In doing so, they found that the combination of park size, ecological context and projected effects of climate change leave many of the parks' species, ecological systems and processes vulnerable to change (Svancara 2010). This vulnerability can be mitigated by activities that reduce threats both internal and external to parks (Baron et al. 2008a,b) and maintain or even increase connectivity through collaborative management with landowners and managers in the matrix lands and waters between parks and other conservation areas. However the combined holdings of America's parks, natural areas, wildlife refuges, wilderness and other conservation areas fail to represent the full range of our natural and environmental diversity (often referred to as geophysical features), species occurrences and ecological settings. The location of conservation areas is biased towards steep slopes and poor soils at high elevations. (Scott et al. 2001a; Aycrigg et al. in press; NABCI 2011). For example, assessments of national park units indicate that there are eight ecoregions which do not contain any national parks with significant natural resources (Svancara 2010). Overall, these analyses support calls by the Second Century

Commission to conduct assessments of how well our nation is conserving biodiversity (National Parks Second Century Commission 2009). Gaps that are found may represent opportunities for strategic growth within the National Park System or other types of conservation areas to fulfill a vision of a national system of conservation areas that captures the full range of America's biological diversity.

Second Century Commission Charge

The call by the Second Century Commission for "Actions to preserve America's natural and cultural resources by strengthening the Park Service's capacity to preserve park resources and extend the benefits of the National Parks idea in society by creating new National Parks, collaborative modes of corridor conservation and stewardship, and expand the park system to foster ecosystem and cultural connectivity". The Commissions science and Natural Resource Committee challenged America "to build the National Park System to ensure its long-term health in a changing landscape" (Colwell et al. 2009). While the "Future Shape of the National Park System Committee" identified a need to develop a strategic vision for the National Park system in the context of a larger Informal National System of conservation Areas(Galvin et al. 2009). These same issues were addressed by the Planning Committees report to the National Park System Advisory Board (G. Long personal communication). To address these charges requires several things. The first is a full conservation assessment of what the current National Park System and other conservation areas hold. Secondly, it requires a more detailed stipulation of the conservation vision and goals for the NPS in its second century. What will our goals be? Will the emphasis be on species, ecological systems, ecological services, environmental settings, or a mix? Such a vision is needed to provide a clear set of objectives for the next century of NPS park managers to fulfill

Based on the work of the Second Century Commission, the existence of an INSCA, and several analyses and assessments of these conservation areas, we identify five opportunities for conservation planning and assessment by the NPS to:

1. **Develop an ecological vision of what the National Park System will look like in 2066 - its 150th Anniversary - and how the National Park System can contribute to the conservation of America's biodiversity.**
2. **Outline specific ecological goals (e.g., for particular ecosystems, geophysical features species, or ecosystem processes and services) for the National Park System.**
3. **Assess how well the current system is doing at meeting these ecological goals in the context of a larger INSCA.**
4. **Identify where strategic growth of the National Park System could help make our informal national system of conservation areas more complete.**
5. **Use these assessments and vision to promote the concept of a national system of conservation areas.**

Below we identify tools and outline methods for conducting these assessments and developing this vision.

Conservation Planning and its Principles: Utility for National Park System

There is a considerable amount of guidance available for assisting the NPS in analyzing how well its current system of units represents the native species and ecosystems diversity in the U.S. and how expanding the NPS system could improve upon that representation as well as the ecological resilience (Walker and Salt 2012) of existing parks. Broadly speaking, this guidance comes from what is commonly referred to as the conservation assessment and planning literature. Conservation assessment and planning addresses two broad questions (Redford et al. 2003):

1) Where should new conservation areas, such as NPS units, be located in order to achieve specific local, regional, or national conservation goals?
2) What kinds of strategies or actions are necessary to achieve conservation of real places on the ground (or in the water)?

The first question is often referred to as spatial planning and the second as strategic planning. Scores of scientific articles have been published on spatial planning, often under the rubric of systematic conservation planning (Margules and Pressey 2000), while many fewer articles and much less guidance has been published in scientific journals about strategic planning. Although many organizations and agencies do these types of planning separately, the most recent advice is that they should be done concurrently (Wilson et al. 2009).

Gap analysis (Scott et al. 1993,2001,2004a,b,c, Rodrigues et al. 2004) has played a major role in conservation planning by gathering and analyzing data sets to determine which species or ecosystems represent “gaps” in the current system of conservation areas. Systematic conservation plans such as the ecoregional assessments of The Nature Conservancy (Groves et al. 2002) took gap analysis one step further by identifying those potential conservation areas to fill the gaps for a particular set of ecological goals.

Many advances in conservation planning methods and tools have occurred over the last decade. Chief among these are better incorporation of ecological processes and functions (Pressey et al. 2007), expanding these functions to include ecosystem services (Kareiva et al. 2011), better inclusion and understanding of the costs (economic and otherwise) of conservation actions, improved planning for freshwater (Nel et al. 2009) and marine ecosystems (Klein et al. 2010), incorporating climate change adaptation considerations (Groves et al. 2012), new approaches to connectivity (Aune et al. 2011), and planning for multiple objectives with tools like Marxan with Zones (http://www.ebmtools.org/marxan.html). All of these advances could be incorporated by the NPS to one degree or another as they consider analyses to better understand what contribution the NPS units currently make to conserving the full range of America's natural resource diversity, as well as how the stewardship of these natural resources might be expanded in a world of climate and land-use change.

At the outset, a useful question for NPS to consider is: why do more planning? The simple but not necessarily obvious answer is that we believe that taking a thoughtful systematic approach to expanding or managing the NPS system will result in a better outcome than intuition alone or best guesses will provide. That is probably obvious. Less obvious and too often overlooked is that any planning effort should carefully consider its purpose, which will use the results, and what decisions will be affected. NPS will need to be clear about the overall purpose it envisions in the NPS system. That purpose will help guide the analyses and conservation planning. For example, one framework suggests that the purpose of conservation planning is to establish a set of conservation areas that are representative, resilient, redundant, and restorative – the Four Rs (Groves 2003). Representative usually refers to a set of conservation areas that contain a pre-determined set of biodiversity features and a range of environmental conditions under which these features occur. Resilient refers to the ability of conservation features (e.g., species or ecosystems) to persist in the face of both natural and anthropogenic disturbance. From this perspective, it incorporates the concepts of population viability and ecological integrity. *Redundant* indicates that a system of conservation areas needs to include multiple examples of the biological and other features for which it is being established so as to increase the odds that these features will persist over time. Finally, restorative implies that a conservation plan or assessment should identify those features that may not currently be viable but could be restored to a viable state over time. Below we provide additional guidance on how the NPS can better incorporate climate adaptation strategies in its current and future system.

These basic principles are embraced to one degree or another, either explicitly or implicitly, by several Department of Interior or Interior-related initiatives. For example, State Wildlife Action Plans (Meretsky et al. 2012) and the guidance for developing these plans include most if not all of these basic principles (www.wildlifeactionplan.org) The National Wildlife Refuge Improvement Act of 1997 established an explicit mission for the NWR system – the conservation, management, and restoration of a national network of habitats as well as the requirement for conservation plans for each refuge to help meet this mission (Gergely et al. 2000). Similarly, the Strategic Habitat Conservation Handbook of the US Fish and Wildlife Service of 2008 (http://www.fws.gov/science/doc/SHCTechnicalHandbook.pdf) embraces most of these principles as well. There has been no comparable system planning effort for the National Park Service since 1972.

Methodological Approaches for National Park Service

Terrestrial ecosystems gap analysis:

For terrestrial ecosystems, the USGS Gap Analysis Program has recently created a national land cover data set. The underlying classification unit in the land cover data set is ecological systems - groups of vegetation communities that occur together within similar physical environments and are influenced by similar ecological processes, substrates, and environmental gradients (http://www.natureserve.org/publications/usEcologicalsystems.jsp). Aycrigg and colleagues (in press) used these data on ecological systems and land cover in combination with the Protected Area Database for the US (PADUS) (http://gapanalysis.usgs.gov/padus) to address three questions that are relevant to the NPS: 1) How well are ecological systems in the US represented within the different categories of protected areas (see gapanalysis.usgs.gov for details on the 1-4 classification of protected areas) and ecological scales of occurrence (Aycrigg et al. in press ; 2) What opportunities exist to achieve increased conservation of ecological systems through changes in public land management? and 3) What percentage of each ecological system is already under some degree of protection (i.e., falls within INSCA)? They found that the ecological systems best represented within the INSCA were sparse and barren systems such as alpine bedrock, ice fields, coastal dunes, volcanic rock and cinder lands, cliffs and badlands. The biggest gaps in ecological system representation were for grasslands and subtropical forestlands, and arid land systems especially those at lower elevations and on richer soils. Previous studies (Scott et al. 2001 a, c) as well as other recent assessments had similar findings (Sayre et al 2012).

The NPS could build on these analyses using the national land cover and protected area database and other data sources to answer several key questions necessary for evaluating the ecological representation and context of the National Park System:

1) Which ecological systems are currently represented in the NPS system and which are not? Of those that are not represented, which of these are represented and which are not in the larger network of conservation areas in the US (i.e., INSCA)?
2) Which ecological systems are underrepresented in the NPS system or by other types of conservation areas in the US? Underrepresentation could be analyzed along two lines: a) the percent coverage of an ecological system within the conservation area system and b) the degree to which the occurrences of an ecological system in the conservation area system fall above or below what is considered adequate for that system to be viable over the long term.
3) Which administrative regions of the NPS and Land Conservation Cooperatives of Department of Interior have the greatest diversity of ecological systems?
4) Where may there be opportunities to increase this representation of biodiversity both nationally and within NPS administrative regions or other types of conservation planning areas (e.g. DOIs Landscape Conservation Cooperatives hereafter LCC's)

These questions assume that the NPS system alone will never be sufficient by itself to provide representation of all the ecological systems of the US.

To answer the questions of where opportunities may exist, additional data sets will be necessary as the current data base of protected areas includes little private land. However GAP has been working with TNC to incorporate their natural areas and to add the National Conservation Easement Database to the next version of PADUS that will be released in June 2012. The individual ecoregional assessments of The Nature Conservancy (available in report form at www.conserveonline.org) provide that crucial piece of information and some of the most important data from those assessments are now available to NPS and others in a national, geo-referenced database (see Maps.tnc.org/USpriorityAreas or http://50.18.62.210/USpriorityAreas/).This database includes information on potential conservation areas that have been identified in each ecoregional assessment as well as the biodiversity features (including ecological systems and targeted species) that occur within each of these areas. State wildlife action plans (www.statewildlifeaction.org) may also serve as a statewide or regional source of information for geo-referenced areas that are important for key wildlife habitats (some state wildlife action plans use “ecological systems” as the basis for wildlife habitats) and species of greatest conservation need (a state wildlife agency term).

One disadvantage to the gap analyses that use only the national land cover dataset on ecological systems and the PADUS database is that there is little or no information about the ecological quality or integrity of the ecological systems. Many of the ecoregional assessments of TNC have taken this into consideration to a limited degree through the inclusion of a “cost layer” in the data sets – usually some surrogate index of landscape integrity that includes such variables as roads, cities, electrical infrastructure, railroads, and other variables related to human use. Such data have been applied globally (Sanderson et al. 2002) – referred to as the Human Footprint index – and can be adopted for regional and national analyses (e.g., Woolmer et al. 2008; Leu et al. 2008).

Other data layers that can be helpful in these sorts of analyses are those that provide some indication of environmental variability. In an era of climate change, conserving the range of environmental variability over which elements of biodiversity (e.g. ecological systems) occur has long been considered a sound conservation approach. Several researchers have proposed using geophysical features such as elevation, soils, soil productivity, slope, and other variables to represent environmental variability. Elevation data sets can be obtained from the National Elevation Dataset [http://ned.usgs.gov] [USGS 2006] The NED data can be arranged into classes at intervals that best meet the needs of the user. Soil productivity classes for the conterminous United States may be obtained from STATSGO data (http://soils.usda.gov/survey/geography/statsgo/). An additional data source is the Soil Survey Geographic (SSURGO) Database (http://soils.usda.gov/survey/geography/ssurgo) that provides significantly improved and more locally relevant soils variables than available in STATSGO. It’s based on county soil surveys and there is coverage over most of the US. These features can serve as coarse filter targets in their own right in a gap analysis or as targets used in relation to a climate adaptation approach that is focused on conserving environmental variability (the metaphorical stage) in contrast with species diversity (the actors) (e.g. Pressey 1995;Hunter et al. 1998; Scott et al. 2001c; Beier & Brost 2010). Later in the section on regional approaches we discuss the use of geophysical features at more detailed scales of resolution (Anderson et al. 2011) to assess and plan for conservation of natural resources. Finally, the PRISM database at Oregon State University (http://www.prism.oregonstate.edu/) contains variables on monthly precipitation, dew point, and monthly min and max temperature, and these data can be used to understand the how climate variability and change shapes current and future conservation opportunities. The conservation related questions that can be asked using these data sets are similar to those listed above for terrestrial ecosystems.

Freshwater ecosystems and gap analysis

Any NPS analysis of ecological representation should also focus attention on freshwater and marine systems as well as terrestrial. For freshwater ecosystems, there are several classifications, all with various advantages and disadvantages. Overlap between freshwater and terrestrial ecosystems in terms of representation is poor, so it is necessary to look separately at freshwater ecosystems. A good starting point for classifications is Freshwater Ecoregions of the World (http://www.feow.org) – a joint product of The Nature Conservancy and the World Wildlife Fund. This classification system is driven by the distribution of fish and amphibians. Jonathan Higgins and colleagues (2005) took this classification system a bit further by subdividing each freshwater ecoregion into ecological drainage units (EDU) and freshwater ecological systems. EDU's have been mapped nationally through the National Fish Habitat Action Plan, and there is a USGS spatial database of EDUs at: http://ecosystems.usgs.gov/fishhabitat .This national fish habitat action plan ranks each EDU for risk of degradation to native fishes. These EDUs could be used in a freshwater gap analysis by NPS, and questions similar to those posed for terrestrial systems could be addressed.

Gap analyses for marine ecosystems

In the marine world, there is a different classification system for ecosystems known as the *Coastal and Marine Ecological Classification Standard: A National Standard to Support Ecosystem-Based Resource Management*. Detailed information about this classification is available at: http://www.csc.noaa.gov/benthic/cmecs. This classification has been adopted as a federal data standard by the US government. Additionally, PADUS has information on marine protected areas taken from NOAA (http://www.mpa.gov/dataanalysis/mpainventory/).

Although this classification exists, it has not been widely applied to develop a geospatial map of marine ecosystems that can be used for any national level gap analysis. Nor has this database been used with the marine protected area data base to conduct gap analyses of marine ecosystems. Although The Nature Conservancy's marine program has published a guide (Corrigan et al. 2007) to doing marine gap analyses, there are few published examples. Good examples of marine system gap analyses include California (Gleason et al. 2006) and Ecuador (Teran et al. 2006). Because marine ecosystems have not been mapped nationally, it is probably not feasible for NPS to do any sort of national-level gap analysis of marine ecosystems but they could be done for select NPS administrative regions for which marine ecosystems are particularly important or threatened. There may also be opportunities for NPS to help protect the marine environment adjacent to coastal (and largely terrestrial) national park units and help develop a national map of marine ecosystems.

Regional approaches

There may be cases where it will make sense for the NPS to conduct gap analyses on a regional scale. There also may be specific NPS regions of Landscape Conservation Cooperatives (http://www.fws.gov/science/shc/lcc.html) where it is either a priority to improve ecological representation or there are opportunities to do so which do not exist in other regions. The advantage of doing analyses at the regional scale is that it can provide a more direct link with policy and management, and there will often be higher quality data sets with which to conduct the assessments. For example, Mark Anderson and his colleagues have developed many useful datasets for these sorts of analyses in the northeastern U.S. In particular, they have produced a number of environmental or biophysical data layers including the definition of 17 broad geophysical settings for the region based on elevation, geological classes, and landforms.

Within geophysical settings, they also estimated landscape complexity and permeability within each 30 x 30 m grid cell. In one set of analyses, they overlaid this information with locations of state Species of Greatest Conservation Need to identify those populations of species that are most likely to be resilient over the long term in the face of climate change (Anderson et al. 2011). In a separate but related set of analyses, they identified the most resilient sites for terrestrial conservation (irrespective of the locations of species of greatest conservation need) based on a classification of geophysical settings, the same analyses of landscape complexity and permeability, and key linkage areas for climate-induced regional movements (Anderson et al. 2012).

Similar environmental data layers are being developed by Nature Conservancy, academic, state, and federal agency teams in the southeastern and northwestern United States. The availability of these data sets allows the NPS to do some gap analyses at the regional scale that would include the representation of environmental variability as well as ecological systems.

Species approaches

National data sets on species occurrences are only available for certain species groups – primarily at-risk plant and animal species as defined by State Natural Heritage Programs and Nature Serve (www.natureserve.org). Their classifications of at-risk species are widely used by the Interior Department, other federal natural resource agencies, the Gap Analysis Program, and many state wildlife agencies. Any gap analysis focused on individual species faces a technical challenge related to the lack of seamless spatially explicit data for species occurrences. At least for some species, efforts are underway to overcome this hurdle (see Cornell University e-bird atlas: http://bird.atlasing.org/). GAP is working towards creating national range maps and distribution models for over 2000 species over their entire range (see gapanalysis.usgs.gov and look for species viewer).

Many of these species are listed as threatened or endangered under the US Endangered Species Act and may be listed as Species of Greatest Conservation Need within State Wildlife Action Plans (Meretsky et al. 2012). It is possible to use these national datasets on at-risk species occurrences in gap analyses related to ecological representation of the NPS system. Because 84% of listed species with recovery plans are conservation reliant, the inclusion of these species in any future national park plan or park expansion strongly implies that the NPS will be obligated to specific management interventions for many of these species (Scott et al 2010) for the foreseeable future. The basic questions that species-specific analysis could address are:

1. How well does the current Informal National System of Conservation Areas capture occurrences of at-risk species?
2. How well does the current NPS system capture occurrences of these species?

3. Where do opportunities exist for future NPS holdings to include greater representation of these occurrences and which of these opportunities may be most critical for the conservation of specific at-risk species?
4. Where do opportunities exist for the NPS to collaborate more effectively with adjacent land owners/managers to manage at risk species in existing parks?

In addition to these sorts of gap analyses for at-risk species conservation, the NPS may wish to undertake species-specific analyses for other selected species. For example, the NPS could conduct a range wide assessment of spatial variation for particular species occurrences in conservation areas (Scott et al. 2001b). Sanderson and colleagues (2002) have outlined methods for conducting range-wide assessments of species, especially wide-ranging species whose conservation will not usually be adequately covered by ecoregional assessments or individual state wildlife action plans. The methods were pioneered for tigers (*Panthera tigris*) and have now been published for jaguars (Panthera onca) and bison (*Bison bison*) as well. The most important features of the range-wide approach include planning for species conservation across the entire range of a species; accounting for the different types of knowledge and certainty that we have about species distribution and population status; limiting recommendations to what is definitively known; and basing recommendations on ecogeographic priorities – that is, a consideration of ecologically distinct populations. Redford and others (2011) have more recently expanded on this range-wide assessment effort to better articulate what it means to successfully conserve a species (i.e., throughout its range).

There are opportunities for linking the results of gap analyses conducted for ecological systems with those conducted for individual or groups of species. For example, Aycrigg et al. (in press) found that grasslands were one of the least protected ecological systems in the lower 48 states. while others (Noss et al. 1995) identified grasslands as endangered nationally and regionally and the 2011 State of the Bird Report (NABCI 2011) reported that 97% of the native grasslands of the United States have been lost and grassland birds have declined from historic levels more than any other continental group of bird species and currently are among the most consistently declining species in the United States. Additionally there are ongoing efforts to conserve and restore the American Prairie (http://www.americanprairie.org/).

These intersections of a declining species whose habitat is at risk and underrepresented in conservation areas and potential cooperators provides an opportunity to fill a conservation gap through strategic growth of the NPS System that is enhanced by strategic partnerships in the state, federal, tribal and private sector. Along a similar line, the NPS has recently launched a migratory species initiative (Elaine Leslie, NPS, pers. communication), and it is likely that this initiative will identify additional lands and waters critical to the conservation of species that currently occur within park boundaries but also migrate beyond them and provides opportunities for new conservation partnerships with partners in Flight and other groups (http://www.climateconservation.org/images/Papers_and_Reports/Recent-progress-on-wildlife-corridor.pdf).

One tenth of one percent of the 518 ecological ecosystems in the United states are not found in any protected area, while 68% fall below the 17% conservation target set by the Convention of Biological Diversity (http://www.cbd.int/sp/targets) The majority of under protected ecological systems are found on low elevations and on moderate to high productivity soils (Aycrigg et al. in press).

These underrepresented ecological systems especially the least protected systems such as Edwards Plateau Mesic Canyon, Tamaulipan Clay Grasslands' and central Appalachian Riparian (Aycrigg et al. in press) represent opportunities to fill gaps strategically in the National Park System and the INSCA. In summary, there are many available methods, tools, data sets and partners with which NPS can analyze the representation of ecological systems, important species, and geophysical features (conservation targets) in its current system and the larger INSCA to identify opportunities for strategic growth of the park system. It would also be important to assess ability of proposed new parks to fill gaps (Wright et al. 1994).**The NPS could use gap analyses to assess its current system of park units for representation of conservation targets across terrestrial, freshwater, and selected marine realms and within LCCs and National Park Service administrative regions (Aycrigg et al. in press).**

1) **Opportunities for ecological analysis include: Using gap analyses to address a specific set of questions related to the vision and goals of NPS (i.e., which ecological systems and/or species are most important to NPS) and identify important gaps for individual parks and the National Park System that a future NPS System could address with strategic growth.**

2) **To the degree possible, tying these gap analyses to other appropriate initiatives and assessments of other state (e.g., State Wildlife Action Plans, Joint Ventures, endangered species recovery plans , etc) ,proposed new national parks (Wright et al. 1994) and federal natural resource agencies or within Interior itself (e.g., migratory species initiative. Leopold Report 2012 within NPS).**

National Park Operations in the Context of Larger Landscapes

The mandate of land management agencies to date, including NPS, largely has been to focus on management within the boundaries of any particular jurisdiction. In the 21st century, two major pressures are pushing to expand this mandate. First, as we mentioned at the beginning of this report, a large body of science is suggesting that existing parks and conservation areas are inadequate to address the conservation of biodiversity in a changing world. This means that conserving a species within any particular park may require working in the context of a much larger landscape. Second, as a result of these findings, land management agencies are beginning to shift their focus from management within the bounds of a jurisdiction to engage in the context of the larger landscape with other entities to achieve conservation. This section will briefly a) discuss frameworks in which to assess and engage in the landscape context, b) provide a brief overview of how climate change adaptation fits within this landscape context, and c) offer an overview of how DOI Landscape Conservation Cooperatives (LCC) may play a role.

Existing frameworks in which to assess the landscape context

The previous Conservation Planning section discussed ways to assess representation nationally as well as regionally, which could be in the context of a larger policy-relevant landscape such as an LCC. Ensuring adequate core conservation areas that are representative of the landscape is obviously important. Equally important is how the larger landscape (or seascape or watershed) within which these conservation areas occur is managed. The sections below offer an abbreviated review of resources emphasizing or evaluating the landscape context. Some frameworks and tools focus more on buffering existing national parks within the context of a larger landscape while others focus on the question of connecting national parks to other core protected areas. While these two concepts of buffering and connectivity can be interrelated, we suggest that the National Park Service consider both of these in the context of larger national parks system planning and individual park unit planning in the 21st century.

Resources for assessing landscape-level threats

One set of existing datasets and analyses focus on threats or potential threats in the form of levels of human activity surrounding parks. The previously mentioned "Human Footprint", is one example of such an existing analysis (see Conservation Planning). This modeling approach can be downscaled to a region or landscape and already has been for the Northern Appalachian ecoregion (Woolmer et al. 2008) and the West (Leu et al. 2008). Another recent analysis examined one of the most pervasive US threats, residential development, in buffer zones adjacent to national parks across the lower 48 states and found that residential development has occurred preferentially near national parks and that this trend is forecast to continue (Wade and Theobald 2010). This increases the chances for incompatible land use practices in areas adjacent national parks (Svancara 2010). Additional data sets that could prove helpful include housing density maps that were prepared for use in looking at wildland-urban interfaces. Volker Radeloff's work (Radeloff et al. 2010) is quite good and their data are readily available through their U of Wisconsin website (http://silvis.forest.wisc.edu/maps/wui/state). Another candidate is Dave Theobald's work on future housing density. More on this data set is available at:

http://cfpub.epa.gov/ncea/global/recordisplay.cfm?deid=203458#Download

Finally, current development can be identified using the USGS National Land Cover Dataset (NLCD) impervious surface layer. While NLCD is already mentioned the impervious surface layer may be a useful stand-alone source for information on development threats. Additionally both the human footprint and buffer zone analyses may be useful for the NPS to assess what parks might already be highly impacted by surrounding human activities as well as areas that remain ecologically intact. Such analyses could also point to priority lands to target to ensure adequate buffers around parks that may be threatened in the near future (Svancara 2010).

Response to these threats could range from landowner incentive programs to collaborative management agreements, conservation easement programs, park expansion, or other stewardship activities with neighboring property managers. Such efforts may promote connectivity to other protected areas and/or enabling species to utilize lands or waters beyond the boundaries of the protected area(s). Although datasets such as the Human Footprint are useful for terrestrial analyses, they are of limited utility for freshwater considerations and virtually of no use for marine gap analyses.

Why connectivity is an important consideration

A wide variety of private and public effort is currently expended on protecting and restoring natural or semi-natural passageways to maintain and enhance connectivity. These range from creation of wildlife friendly road crossing structures to proposals to link continental ranges to conservation of migratory pathways for ungulates (Hilty et al. 2006). These are a result of an increasingly fragmented natural environmental where relatively small protected areas are increasingly isolated from one another. An increasing body of science shows that smaller and more isolated protected areas are more likely to lose species over time. Given this, an important consideration for individual parks and for the configuration of the park system in the context of other protected areas, is the question of park size and current and potential future isolation. Given that species ranges change in time and space, exacerbated by climate change, considering connectivity at the landscape scale is important (Svancara 2010). In the table below, we briefly summarize the levels of biodiversity, scale, and goals which must be addressed when planning for connectivity (from Hilty et al. 2006):

Levels of biodiversity Individual (of a species)
Deme (of a species) Species
Community Landscape
Spatial Scale (of linkage)
Local (e.g., underpass)
Regional (e.g., river corridor)
Continental or cross-continental (e.g., mountain range)
Potential Goals
Daily movement (e.g., access to daily resources)
Seasonal movement (e.g., migration)
Dispersal (e.g., genetic exchange, mate finding)
Habitat (e.g. wide greenway corridor)
Long-term species persistence (e.g., adapt to global warming)

As suggested in the conservation planning section, being clear on the target is important and for any one park or complex of parks and other protected areas, there may be a range of connectivity goals.

Some examples of existing landscape and seascape-level prioritizations and connectivity exercises

Other datasets, analyses, and landscape conservation priorities that the NPS may want to examine are those led by non-governmental organizations (NGOs) often with substantial engagement of scientists. For example, one of the older and better known landscape-level visions is the Yellowstone to Yukon (Y2Y) mountain corridor, which remains one of the most intact mountain ecosystems in the world but is experiencing significant levels of development including increased housing, recreation, and natural resource extraction. The Y2Y NGO envisions a series of core protected areas, often with the cores anchored in one or more national parks, connected by a series of corridors (www.y2y.net). The proposed landscape level design, the downscaled local planning and action, and analyses and priorities of actions around potential threats such as climate change are based in various scientific analyses (Chester and Hilty 2012).

The collaborative science and planning for the Two Countries One Forest Region (2C1F) in the northeastern US and Canada is another example of regional data layers, scientific analyses, and planning priorities that have been produced under the umbrella of an NGO and associated science partners. Their interactive map Atlas (http://www.2c1forest.org/atlas/index.html) offers three ways to examine the human footprint, a few different types of connectivity analyses, and other information that contribute to examining parks and protected areas in the region in the context of the larger landscape. The Wild Lands Network (www.twp.org), which seeks to conserve continental corridors across North America, has conducted a series of connectivity assessments, the latest of which focuses on permeability analyses as a means to map landscape connectivity (Theobald et al. 2012). The Nature Conservancy ecoregional plans, mentioned previously, incorporate gap analyses, some connectivity analyses, as well as identifying place-based priorities, and most of these assessments can be accessed online (http://east.tnc.org/reports/all_assessment_docs). These and other resources from the conservation and science community could serve as data sources, already completed analyses, and types of analyses that the NPS may want to use as they consider priority places to engage across larger landscapes.

Additional resources are available at the state level. The Western Governors Association passed a resolution a few years ago (http://www.westgov.org/wildlife) mandating all states to begin identifying and protecting corridors throughout their states. All western states now have connectivity maps. One of the more thorough analyses was conducted in the state of Washington (e.g., http://www.dfw.state.or.us/conservationstrategy/docs/pac_nw_wl_connections_ws_102008/Wildlife%20Habitat%20Connectivity%20in%20Washington.pdf).

Many states have also conducted various other helpful analyses. One example worth highlighting is in the state of Vermont where they examined the transportation network to understand the potential current and future bottlenecks for wildlife created by the road network (Beckmann et al. 2010).

Examples of existing large landscape conservation initiatives

In addition to the planning and prioritization examples provided above, there are also several good examples of functioning landscape-level initiatives that the NPS could evaluate as potential models for some of its future efforts.

- Within Department of Interior, the National Wildlife Refuge System has been successful in conserving its target of migratory waterfowl through a stepping-stone network of conservation lands and waters (http://www.fws.gov/refuges/; Pidgorna 2007; Rupp 2009). Given the decline of songbird populations as well as their popularity with the birding community (NABCI 2011), one suggestion for the NPS to consider is whether the NPS System could place an emphasis on conservation of migratory songbirds as a target for future growth of the National Park System? This may be particularly important in under-protected regions such as the Great Plains. There are many resources on migratory bird species that could be helpful: a) the North American Bird Conservation initiative (www.nabci-us.org/), b) conservation plans developed for Landbird - www.partnersinflight.org/cont_plan/ ; for waterfowl www.fws.gov/birdhabitat/NAWMP/index.shtm; for shorebirds www.fws.gov/shorebirdplan/USShorebird.htm ; and for waterbirds www.waterbirdconservation.org/, c) the State of the Birds Reports (stateof thebirds.org) or recovery plans for an endangered species (http://www.fws.gov/endangered/species/recovery-plans.html).

- The management of grizzly bears and the recovery plan in the Greater Yellowstone Area (GYA), which mandated coordination and collaborative management across a patchwork of multi-jurisdictional lands across the region (www.fws.gov/mountain-prairie/species/mammals/grizzly) is a successful model of landscape collaboration for single species. Given the decline of difficult-to-manage larger species, particularly carnivores and ungulates, the NPS may be able to catalyze similar collaborations in other areas where suites of such species could be conserved.

- The Adirondacks State Park offers a unique example of integrating public and private land management under one plan. The Adirondack State Park is the largest park in the contiguous U.S. and more than half is owned privately. The Adirondack Park Agency oversees development plans of all private land-owners as well as activities within the state owned Forest Preserve to ensure that all activities are compatible with the park vision (http://visitadirondacks.com/adirondack-mountains/adirondack-park.html; http://apa.ny.gov/). This model is compelling because it proactively defines a functional park as an area that includes private and public lands and manages activities on all lands in accordance with a conservation vision regardless of the land type. Are there other places where the NPS could serve as a catalyst for a unified landscape plan with similar type mechanisms that would help maintain the integrity of the park and surrounding landscape?

- Appalachian National Scenic Trail works across swaths of public land, state land and private lands and interacts with local private clubs, state and multiple federal agencies while under the management of the NPS. While this example is focused on recreation, it offers an example of how the NPS successfully works across multiple jurisdictions and with different partners (http://www.nps.gov/appa/index.htm http://www.appalachiantrail.org/). Where multiple national parks and/or other protected areas serve as core areas and where connectivity for wildlife is deemed important, could the model of the Appalachian Trail management(http://www.nps.gov/appa/index.htm) be used to manage wildlife corridors across multiple jurisdictions?

- The endangered Florida manatee (*Trichechus manatus*) found in freshwater, brackish and saltwater of Biscayne and Everglades National Park and several wildlife refuges provides an example of a trans-boundary species that receives management support outside the Park comparable to those found inside. Beyond the park, marine sanctuaries, wildlife refuges, counties and municipalities enforce protection for species as does the US Endangered Species Act (http://ecos.fws.gov/speciesProfile/profile/speciesProfile.action?spcode=A007) while the United Nations Environmental Program provides guidance for management activates throughout the range of the Florida manatee regardless of the jurisdiction a manatee finds itself in (Deutsch et al. 2003; http://www.cep.unep.org/meetings-events/vi-spaw-cop/manatee-report-1.pdf).

Managing existing park units within the landscapes in which they occur may be as important to conserving the biological resources within the NPS System as strategic growth of the system. **To that end, the action items we identify below include opportunities for NPS to:**

1. **Identify where land-use adjacent to park may compromise the biological integrity of a park:**

    a. **Identify park units for which land-use activities adjacent to the parks are known to currently pose significant threats to biological resources within the parks.**

    b. **Conduct scenario analyses and development forecasting for park units that are likely to be impacted in the future by significant land-use activities adjacent to their borders.**

2. **Identify where there may be opportunities to mitigate these impacts**

a. **Using one or more of the landscape-level tools identified in this report (e.g., human footprint, development forecasting, and connectivity analyses), analyze and evaluate what sorts of activities (and where) the NPS might undertake collaboratively with private and public partners to improve the management of matrix lands and waters adjacent to these parks.**

b. **Identify where there may be opportunities to undertake activities that could mitigate or abate current and/or future negative impacts.**

c. **Explore the examples mentioned in this report as well as others of successful landscape-level initiatives to determine if any could serve as a model for replicating elsewhere within the National Park System.**

3. **Identify sets of parks where maintaining connectivity may increase the probability of species persistence or maintenance of particular processes.**
    a. **Use geospatial analyses to identify best routes for conserving ecological connectivity over the long term**
    b. **Develop mechanisms to work across various land ownership categories to maintain and/or restore priority connectivity areas.**
    c. **Expansion of the national park system or other protected areas may be a tool for consideration to enhance a functional protected area network within a region.**

In addition we identified several lessons learned from multi-party management of matrix lands. These include:

1. **Private and public partners can improve the management of matrix lands and waters adjacent to parks.**
2. **There is a benefit to conducting scenario analyses and development forecasting for park units that are likely to be impacted in the future by significant land-use activities adjacent to their borders.**
3. **There are opportunities to explore the examples mentioned in this report as well as others of successful landscape-level initiatives to determine if any could serve as a model for replicating elsewhere within the National Park System.**

Considering Climate Change

Although this subcommittee was asked to consider how climate change and the related topic of connectivity should be considered in assessing the adequacy of ecological representation in the National Park System, we wish to acknowledge at the outset that there have been previous efforts to do this (Baron et al. 2008a,b and Svancara 2010) and there are numerous efforts underway in the NPS and other agencies that address this issue to some degree. For example, the NPS is already engaged in adaptation planning (http://www.nature.nps.gov/climatechange/docs/AdaptationBrief.pdf) that involves, among other objectives, re-framing park management goals in the face of climate change, scenario planning in several pilot park units, risk assessment for park units facing immediate impacts such as sea-level rise, and increasing monitoring efforts focused on climate change impacts. In addition, NPS staff members are engaged in a USFWS-led national strategy on adaptation (*National Fish, Wildlife, and Plants Climate Adaptation Strategy January 2012)* that is currently available for public review (http://www.wildlifeadaptationstrategy.gov/public-review-draft.php). Additionally, the Environmental Protection Agency conducted an assessment of adaptations for climate sensitive ecosystems and resources in national parks and other public lands (West et al. 2009; Baron et al 2008a, b). As a result, the management actions we identify and opportunities for making a difference that we suggest here will be brief and are meant to supplement and complement the adaptation efforts already underway within the NPS. In particular, we will focus on a few new publications related to adaptation that could enhance ongoing efforts of the NPS, especially in relation to the topic of strategic growth of the NPS to mitigate the effects of climates change on parks and their natural resources.

Changes in species distributions, shifts in date of arrivals of migrants and onset of breeding as well as alteration of consistent with climate change projections have occurred. . The details of these and other impacts have been documented elsewhere (e.g., Inter-governmental Panel on Climate Change reports (http://www.ipcc.ch/). Here we focus on how to plan for climate change in the context of large landscape conservation. What has changed in conservation and management because of climate change? While one can debate a long list of changes, two fundamental shifts are irrefutable: 1) we can no longer manage for past baselines of species distributions and habitats; we know that species are moving, systems are changing we need to be managing for resilience and transformation, and 2) we are moving toward management within the context of larger landscapes and conservation networks. Landscape level connectivity discussed above is one of the major opportunities for helping species and systems cope with climate change (Heller and Zavaleta 2009), and there are also a suite of other tools and considerations that the NPS may want to consider in planning for a well-connected and resilient system of National Parks within the context of larger landscape engagement and climate change.

Responding to the threat of climate change

A number of scientists have published recommendations on climate change adaptation. Below is a relatively high level summary of what these reviews ultimately recommend (from Chester et al. 2012):

- Protect appropriate and adequate space:
  - Maintain/enhance connectivity between those areas
  - Protect climate refugia (e.g., those areas least likely to undergo significant climate induced changes, or those areas that will likely house suitable climate conditions in the future but are not currently occupied).
  - Make conservation planning more dynamic by taking shifting species ranges into account when designing reserve networks

  - Insure that the full geographical, geophysical and ecological range of a species is represented in conservation areas.
  - Increase the size and number of conservation areas
- Reduce non-climate stressors:
  - Repulse invasive species, pests, and diseases
  - Sustain ecosystem processes and functions
  - Implement ecological restoration
  - Plan for human responses to climate change that may entail additional threats to biodiversity
- Adopt adaptive management:
  - Study management interventions and species responses
  - Monitor changes and interventions
  - Implement ecosystem-based adaptation (EBA) practices
- Consider species-specific interventions
  - Protect and create essential habitat and connectivity areas
  - Consider translocation (also called assisted migration, assisted colonization and managed relocation) and/or captive breeding
  - Reduce non-climate related threats.

In addition to this brief summary, Groves and colleagues (2012) have made several overlapping recommendations for how to revise existing regional and landscape conservation plans as well as initiate new ones that incorporate adaptation. Their approaches include:

1) Conserving the geophysical stage (see Mark Anderson 2011 and work discussed under earlier conservation planning section), 2) protecting climatic refugia, 3) enhancing regional connectivity, 4) Sustaining ecosystem process and function, and 5) capitalizing on opportunities emerging in response to climate change such as carbon markets. The strength of these approaches is that they are relatively robust to the uncertainties associated with climate change.

Along similar lines, an interagency and inter-organizational task force of adaptation experts has recently developed a framework for incorporating adaptation into existing landscape conservation plans. This framework, available at www.databasin.org/yale , focuses on mapping data layers that can be useful to conservation planners concerned about adaptation and also provides links to existing data layers that NPS planners and others could utilize.

Finally, Cross and colleagues (2012) have advanced a useful framework for developing landscape-specific adaptation strategies – the ACT or Adaptation for Conservation Targets framework – especially for use in natural resource management planning and decision making. This framework has been tested with federal and state agencies in the southwestern U.S. and elsewhere and is likely to be a useful approach to adaptation planning for many national park units.

Key Points on and Opportunities for Adaptation

While these new frameworks and summary reviews may enhance current NPS adaptation efforts, there are a few key additional points to consider. Below, we elaborate these points with opportunities in bold:

- One of the most important approaches we can take is to increase a system's resilience to change and the probability that species within the system will survive into the next century. The first step in increasing the chances of this happening is to secure a species' habitat in conservation areas across the full range of its geographical, geophysical and ecological distribution. **This securing of habitat is a possible goal for the National Park Service to focus on for a select set of species (i.e., for the conservation target species NPS might select as part of its long-term conservation vision) and in conjunction with the INSCA.** Climate change adaptation planning requires this identification of focal features of concern, such as target species or ecological processes, and the setting of goals for these features.

- Under any set of circumstances, there is a large degree of uncertainty associated with climate change impacts and adaptation planning. One of the most effective tools to enable priority management and planning actions to occur where there are high levels of uncertainty is scenario planning (Cross et al. 2012). Scenario planning allows stakeholders to assess whether a management action would be a priority even given different scenarios of climate change, for example, and therefore can be very effective at moving folks beyond 'climate change paralysis'. Doing scenario analyses across multiple jurisdictions can be challenging, however, as different land owners often have different goals. That said scenario planning can, when used in a participatory context, provide a bridge from which to engage in multi-jurisdictional management plans. **Fortunately, the NPS is already engaged in scenario planning at a set of pilot park units (http://www.nature.nps.gov/climatechange/docs/SPlanningOverview.pdf) and may be able to expand this effort to other units as lessons are learned from pilots and resources allow.**

- **It is critical that the NPS does not artificially try to retain park unit's in particular static conditions if climate change is resulting in the redistribution of species beyond boundaries.** It is for this reason alone the NPS must look at conservation in the larger landscape context. If there are other places that are better suited in the long term for a species or ecosystem to persist, the NPS may not need to focus resources to those species or that ecosystem or it may need to help transition a species to a new range of distribution. For example, Sprague's pipit (*Anthus spragueii*) is a sensitive grassland bird whose summer breeding temperature parameters appears to be shifting north. It may be possible across a large landscape such as the northern Great Plains to change grazing regimes north of current habitat that could help facilitate a shifting or breeding habitat northward (K. Ellison, personal comm.). For each jurisdiction within a larger landscape to consider only what falls within their bounds will fail to address both species shifting out of those boundaries as well as species that may shift in. Ultimately, long-term management in the context of shifting climates must address these matters for the National Park System and the U.S. as a whole at multiple spatial, temporal and ecological scales to proactively conserve biodiversity during this time of climate change.

Potential Role of LCCs

As science increasingly points to the need to plan for conservation at a landscape scale, the DOI has created Landscape Conservation Cooperatives to support work at this broader scale. Landscape Conservation Cooperatives (LCCs) within DOI include 22 large landscapes that cover the United States but also spill over into neighboring countries. LCCs "seek to identify best practices, connect efforts, identify gaps, and avoid duplication through improved conservation planning and design. The LCC's provide a forum where "Partner agencies and organ*izations coordin*ate with each other while working within their existing authorities and jurisdictions." (http://www.fws.gov/science/shc/lcc.html). LCCs could play a number of potential roles in assisting the NPS to work at larger landscapes and across multiple jurisdictions (Meretsky et al. 2012). For example, LCCs could be useful for pulling together relevant stakeholders to identify research priorities (Fleishman et al. 2011) and conduct planning and prioritization across the landscapes they represent. They also could become collaborative units where agencies interact and agree on loosely knit priorities and approaches to undertake across multiple jurisdictions, perhaps something like the Greater Yellowstone Coordinating Committee (http://fedgycc.org/). NPS is already engaged with LCCs, supporting five full-time positions that focus on some of the most climate-vulnerable park resources (http://www.nature.nps.gov/climatechange/docs/AdaptationBrief.pdf). In addition, LCCs are funding targeted research and are one mechanism to help fund the limited research capacity that exists within NPS. Finally, LCCs also offer a policy forum in which the research results that point to needed management actions could be scaled up or down as conditions warranted. Depending on how these early engagements with LCCs develop, the NPS may want to consider further engagement with LCCs to help with the science and implementation of adaptation planning.

Conclusions

The National Park Service's second century will be one of unprecedented environmental challenges and opportunities that require management and policy responses at scales from local to global. Park managers will need to manage threats to park natural resources outside as well as within park boundaries. In this report we have identified the tools and data sets that will be needed to develop a vision for the future of the National Park System and maintain the ecological resilience, diversity and environmental health of individual parks and the National Park System in the context of the larger informal system of conservation areas. However, meeting these new challenges will require new partnerships, new skill sets and new ways of thinking. New partnerships between land managers and researchers will be required to identify policy and management relevant questions at multiple scales and conduct the research needed to answer the questions and implement needed management actions in an adaptive management framework that allows everyone to learn while doing.

We purposely have not identified specific areas for new national parks. It is not for lack of ideas on our part. However, we believe that development of a detailed vision containing specific areas for strategic growth of the National Park System should come from a transparent analysis of available information to identify gaps in the current system and from opinions of interested parties gathered together in a systematic and objective fashion. That said, we have identified species, geophysical features and ecological systems under-represented in the National Park System and the tools, processes and data sets needed to further assess representation, redundancy and resiliency of natural resources in national parks as well as the projected effects of climate and land-use change on the integrity, diversity and health of natural resources in the parks. Finally, we have provided guiding principles (Representation, Redundancy, Resilience and Restoration) and tools by which the National Park Service might develop a vision for what the National Park System and a more informal national network of conservation areas for the US might look like in 2116, the 200th anniversary of the National Park Service. We have also documented methods by which conservation planning and assessment might be conducted to identify and fill the gaps in the National Park System. These tools, principles and processes may also be used to assess, evaluate and prioritize proposals for new parks or expansion of existing parks. Such planning and assessments are needed to maintain a National Park System that will contain the scenery, natural objects and wildlife of 22nd century America for the future enjoyment of the American people.

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