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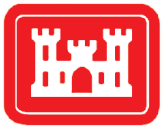

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Case Study Application of the Biodiversity Security Index to Ranking Feasibility Studies for Ecosystem Restoration Projects of the U.S. Army Corps of Engineers

Richard A. Cole

April 2016

Environmental Laboratory

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Abstract

The Biodiversity Security Index (BSI) was applied to 23 project sites ranked for restoration feasibility study annual funding by the U. S. Army Corps of Engineers. The sites were selected to represent a wide range of geographic, ecological, and engineering attributes. The BSI application method described here relies largely on data presented in the NatureServe Explorer database. Data used to calculate the BSI is summarized for each site. BSI score variation among the 23 sites is influenced by three variables: the total number of species that are moderately to highly vulnerable to extinction (G1-3) as indicated in NatureServe Explorer, the scarcity weights placed on G1-3 levels of vulnerability (greatly imperiled, imperiled, vulnerable), and species distinctiveness as indicated by the number of American species in the taxonomic family. BSI scores are compared to the scores of an existing resource significance index (RSI) used to rank the projects for annual Federal budget allocation. The correlation of log-transformed BSI and RSI scores explains half of the variation ($R^2 = 0.50$). Habitat size and resource scarcity appears to explain much of the correlation. The RSI does not discriminate among the projects as well as the BSI. Score differences probably result from the emphasis placed on habitat scarcity by the RSI and species scarcity by the BSI. Possible issues pertaining to BSI use for feasibility study ranking are discussed and compared with the RSI.

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Preface

The U.S. Army Corps of Engineers Civil Works Program is authorized to carry out aquatic ecosystem restoration and protection as long as those actions improve environmental quality in the Federal interest. The protection aspect of the authority implies a national objective to sustain the diverse ecosystem resources of the Nation for an indefinitely long time. Congress also requires that project benefits at least equal the costs for all civil works, including ecosystem restoration. Corps planning policy guidance separates national economic development (NED) aspects of the Corps project planning objective from a national ecosystem restoration (NER) aspect. It also requires NED benefits to be measured in monetary terms for cost-benefit analysis and NER benefits to be measured in nonmonetary terms for cost-effectiveness analysis.

For various reasons, a single NER benefits metric indicating improved sustainability would be ideal, but eluded the Corps until the Biodiversity Security Index (BSI) was suggested in 2010. It is focused on restoring the long-term viability of unsustainable species populations in the context of supportive and self-regulating ecosystems. The BSI incorporates long term viability of scarce ecological elements into the value it represents and is broadly applicable across Corps projects and programs. This is in sharp contrast with metrics now used in project planning and program ranking of projects for recommended appropriation of annual budget. The metric used to rank projects for recommended budget appropriation is a resource significance index (RSI) composed of seven criteria. The RSI cannot be used for project planning and is influenced only slightly by species and sustainability criteria, being dominated by habitat variables. This report responded to a request for a case study comparison of RSI and BSI ranking of recommended project feasibility studies for annual budget appropriation.

For their review and related discussions, the author would like to thank Dr. Bruce Pruitt and Dr. Michael Guilfoyle at ERDC, and by Shawn Komlos at IWR. Ellen Cummings provided data for project ranking by use of the RSI. Part of the funding for this project was provided by IWR under the direction of Robert Pietrowsky.

COL Jeffrey R. Eckstein was the Commander of ERDC, and Dr. Jeffery P. Holland was the Director.

1 Introduction

Background and Purpose

The U.S. Army Corps of Engineers (Corps) is required by law to justify its investments of public funds in civil works projects by showing that the benefits at least equal the costs (Cole 2014a). This applies to all benefits and costs regardless of whether they are measured in monetary or nonmonetary terms. Before 1986, all projects planned and implemented by the Corps had public use benefits that were justified in monetary terms. That changed in 1986 when the Corps was programmatically authorized to improve degraded environmental quality at existing Corps projects. That authority included improvement of resource nonuse value, which motivates the protection of resources from consumptive use. Such value might include for example, the improvement of habitat for fish and wildlife to decrease their risk of extinction as long as the habitat is dedicated to that output by prohibiting counteractive uses. Because the value does not derive from present use of resources it accrues to both present and future generations in the form of use options. The National Environmental Policy Act refers to this form of environmental value as national heritage and establishes its preservation as a national goal. More specifically, the Endangered Species Act (ESA) established maintenance of fish and wildlife heritage as a national goal. Corps project planning policy prohibits monetization of nonuse value because the methods are unreliable. It must be indicated in other ways.

In 1996, the Corps was programmatically authorized to carry out aquatic ecosystem restoration and protection projects anywhere in the United States as long as the associated costs effectively improve environmental quality in the public interest at any location a nonfederal sponsor is willing to share the cost (Section 206 of the 1996 WRDA). Required protection of the restoration outputs determines that they are valued by the public for their contribution to preserving national ecological heritage. Therefore the measurement of benefit justifying investment should indicate significant contribution to the preservation of national heritage. National heritage associated with aquatic ecosystems is particularly imperiled, as indicted by the number of species that are at risk of extinction (Ricciardi and Rasmussen 1999, Cole 2009)

Like other Corps projects, the benefits from restoration investments must at least equal the costs, but cost effectiveness, and not benefit-cost analysis, is the analytical approach authorized in Corps project planning guidance (USACE 2000). Consistent with the protection aspect of the 1996 authority, Corps policy forbids use of the existing monetization technique for measuring nonuse value. However, existing methods for measuring environmental benefits from restoration projects have contributed to confusion in communication among writers and reviewers of project feasibility studies, cost sharing sponsors, the Corps and the Office of Management and Budget (OMB), project and program planners, and Corps policy analysts (Stakhiv et al. 2003, Cole 2014b, c). A new metric, the Biodiversity Security Index (BSI) was developed to address the problematic issues (Cole 2010, 2014d).

The Corps and other Federal agencies are required by the Government Performance and Results Act (GPRA) to annually recommend Federal budget allocation to its various activities based on contributions to National welfare. For the Corps, this includes project planning and construction activities. Recommendations are made to OMB. The number of projects planned and constructed to carry out ecosystem restoration and protection has increased rapidly and more project feasibility studies and construction are now proposed than can be funded out of the annual budget. The rank order is critically important for determining when and if a project gets funding approval. Because ranking is redone annually to include new projects, projects ranked low have a low probability of ever being funded. This places substantial responsibility on the Corps and OMB to recommend projects highest in contribution to the national welfare, which, in the case of Corps restoration projects, is the welfare associated with national heritage.

A ranking method based on a resource-significance metric was developed for Corps use in 2004 and has been modified several times since. A recent description of the unnamed metric is provided in USACE (2010) and in Cole (2014c). It is referred to here as the Resource Significance Index (RSI). In brief, the RSI places high emphasis on technical recognition of habitat scarcity and connectivity, including within that emphasis how well proposed projects are likely to restore a more natural geology and hydrology. It places much less importance on the institutional recognition of species scarcity. The BSI takes a very different approach by emphasizing species scarcity. Both metrics indicate gross benefit; cost is not included in either.

Background on nonuse metrics, BSI development, and conceptual comparison to other restoration metrics used by the Corps are described in Cole (2014 a, c, d), but a case study of BSI application to projects that have been ranked using existing Corps metrics for feasibility and construction had not been completed until this study. The purposes served here are to describe the method by which the BSI is applied to rank project feasibility studies, show how the important attributes of the BSI contribute to score value, show differences between the BSI and RSI across 24 representative projects, and describe complications that arose during the application.

BSI Development Concept and Principles

The BSI was developed to improve restoration benefits measurements in a way that is consistent with national environmental policy, Corps project planning policy, and the state of ecological science (Cole 2010, 2014d). Unlike existing metrics now used by the Corps, the BSI is designed to be comparable across projects in the program. Different forms of the BSI are used to rank projects for feasibility study and for construction. Because feasibility study is required to inventory necessary information pertaining to the risks affecting the viability of ecological resources in the project area, a simpler form is used to rank feasibility studies:

$$\text{BSI} = \sum_{s=1\ldots n}((wD)(wG))_s$$

s = indicator species
wG = policy weighted indicator of species security status
wD = policy weighted indicator of species distinctiveness

The BSI ranks feasibility studies based on the scarcity of ecosystem elements. It is based directly on how secure species are from global extinction (an indicator of long term sustainability) and the taxonomic distinctiveness of species (an indicator of the diversity of unique attributes held within the species). It not only indicates the security of unique species attributes from extinction but also indirectly indicates the scarcity of ecosystem elements needed to support the presently unsustainable species. The unsustainable species are indicators of the ecosystem diversity required to sustain the scarcest elements. As such, the BSI indicates the relative scarcity and value of ecosystems. For the purposes of this study, the policy weights used for security status are proportional to the number of viable

populations commonly needed to establish various levels of security, including a sustainable "secure" state. The distinctiveness term is assumed to have a policy weight of 1.0 in this study. The weighted terms are multiplied for each species and then summed to produce the BSI score. The total score is equal to the average species score times the total number of scored species. Details are provided in the methods section.

To preserve a standard approach, the data used to represent attribute scarcity are obtained from only one nationally comprehensive database, NatureServe Explorer. It is widely used by nongovernment and government conservation organizations and is maintained by NatureServe, an independent nongovernment organization (Cole 2010, NatureServe Explorer 2013**).** NatureServe Explorer plays a critical role in making the BSI practical for indicating restoration benefits and consistent with scientific assessments of ecological resource condition.

Development of the BSI was based on several assumptions about the benefits intended from implementation of the Corps ecosystem restoration program:

- The fundamental and essential basis of ecological resource quality is life that has diversified into species that interact with each other and their physical environment to sustain self-regulating, nurturing ecosystems.
- The public "demand" that life be sustained in its diverse species forms, as indicated by the ESA and other law, is firm evidence that the public values the diversity of life and each species that contributes to that diversity.
- Ecosystems are continuously changing in species composition and form, but ecosystem diversity can be sustained nationally as long as the overall diversity of species and their environmental requirements are sustained within ecosystem settings that function largely without human intervention.
- Species continuously change through evolution and no species is sustainable in the very long term, but the human-caused acceleration of species decline and extinction is causing a net loss in diversity inconsistent with a national desire to preserve our natural ecological heritage.
- Ecological resource information is most consistently, thoroughly, and clearly organized and available at the level of species (since the early

19th century), making it the most practical unit of scarcity and value measurement among alternatives (e.g., ecosystems, habitats, subspecies).

- The difference between the desired condition of species needed to preserve an intact ecological heritage and the existing species condition indicates the viability (sustainability) of the ecological resources—and, in general, the effort required to restore the ecological resources to the desired viability level.
- Species are defined by their attributes, which are determined by genetic endowment and environmental interactions.
- Species vary in the distinctiveness of their attributes—some species are similar to many other species in their taxonomic family while other species are one of very few in the family and differ much more substantially from all other species.
- The security of distinctive species attributes from extinction (species sustainability) is a comprehensive means of indicating the scarcity and value of the ecological resource quality that is the focus of the Corps ecosystem restoration and protection program.

As applied for ranking project feasibility studies, the BSI does not consider residual risk, which requires feasibility study. Thus the metric for ranking feasibility studies is about potential only—what might appear in the project area if all of the risks facing species restoration could be effectively managed by the project as very generally characterized. A separate index for project construction includes a risk term. The data were not available to evaluate it in this case study.

2 Methods

General Considerations

The BSI was applied to 24 ecosystem restoration projects ranked in past years during the annual budget cycle. They were selected to represent a wide size, geographic, habitat, and engineering range of projects. Some of the project information that is now required for ranking projects is essential for BSI application for feasibility study ranking. The information used to calibrate the two BSI variables was determined from NatureServe Explorer. Additional information was determined from project descriptions available in Corps documents and from other readily available sources (usually internet based) when needed to complement NatureServe Explorer. NatureServe Explorer organizes species information by state, county and hydrologic unit**.** The 8-digit Hydrologic Unit Code (HUC) was used in this study to identify hydrologic unit size to be consistent with the Corps emphasis on a watershed approach.

Global resource scarcity is most fundamentally indicated by a conservation status category determined by NatureServe for each species, which is weighted in the BSI for this analysis in inverse proportion to the estimated security level and sustainability. The global conservation status indicates the security of the species from global extinction—its long-term viability. Species viability is indicated by the number of viable populations often required to reach a generally secure G4 status (secure, but showing possible signs of initial decline). For most species, the number of populations required to increase to the next level is about 4 times the number required to reach the existing level (Stein 2008). Thus the progress of 1, 4, 16, and 64 corresponds to G4, G3, G2, and G1 species respectively. A policy decision might be made to modify the weight for some justifiable reason other than the security of the species (Cole 2014c). Natureserve Explorer offers an opportunity to use a national status in place of global status. The differences are infrequent and small.

An assumption was made for this study that no species is considered for restoration potential if it is not categorized as G1, G2, or G3 conservation status (highly imperiled, imperiled, and vulnerable). The conservation status is weighted in proportion to the effort required to restore many species to a generally secure status based on analyses of Stein (2008) and

others (see Cole 2014d for details). Possibly extinct and presumed extinct species (GH and GX) were not included because they cannot be found to restore them. Generally secure (G4) and secure species (G5) are not included because they are already considered sustainable (although G4 species bear watching). The rationale is described more completely in Cole (2010, 2014d). Specific guidelines for species inclusion are summarized below.

The species distinctiveness term of the BSI reflects the assumption that each species varies in its heritage value based on the number of unique attributes that distinguish it from other species. A better way to determine distinctiveness ultimately is to count unique genetic markers through molecular means (Cole 2010). In lieu of that, the simple calculation of the number of American species in the family is used to indicate the "average" species distinctiveness. The underlying assumption is that each species is differentiated from its closest relative by at least one significant attribute so that the average complement of unique attributes of species with only 1 family member (the smallest number in this study) are at least 2,000 times as distinct as a species with 2,000 American species in its family (the largest number in this study). Using the global membership of families is an attractive but less practical alternative because global data are more uncertain for many families and no single reference resource exists as yet (NatureServe Explorer now concentrates on the United States and Canada).

BSI Calibration Guidelines Used in This Analysis

1. To maintain a standard approach, NatureServe Explorer is the only database used to determine conservation status, number of species in the taxonomic family, and records of species occurrence in the project HUC. Appendix I provides detailed directions for the use of NatureServe Explorer to calibrate the BSI.
2. The status of all vertebrate, mollusk, vascular plant species, and crustacean species in isopod, amphipod, fairy shrimp, clam shrimp, tadpole shrimp, freshwater shrimp, and crayfish groups is included for every project in the study comparison. Other groups are excluded because of less adequate documentation of conservation and taxonomic status.
3. Only full species are included. All subspecies, populations and other sub-specific categories are excluded to avoid bias due to incomplete taxonomic description and conservation status in most taxonomic groups.

4. Only aquatic species native to the United States and the proposed project site are included and the original range of the species must include the project area. Aquatic species must live in water or cannot survive without water for essential habitat requirements other than water consumption.
5. Numbers of United States species in the family are calculated based on the number provided by NatureServe explorer. All GX species are excluded. All GH, G1, G2, G3, G4, and G5 species and species of unknown conservation status are included.
6. Only species in the project 8-unit HUC or HUCs are included. The proposed restoration must have some potential for improving habitat known to be used by the species. For example, species known to inhabit only river habitat or saline habitats would be excluded for a proposed improvement of a freshwater lake habitat.
7. When possible to discern, specific needs limiting the species should be provided by the proposed improvements. For example, roosting habitat is the limiting factor for many bat species and restoration that does not reduce that limitation would fail to produce bats.
8. Err on the side of inclusion when species status in the project area allows reasonable possibility of it being positively impacted by the project.

In the case-study descriptions that follow, the location, problem, problem solution, and HUCs used to determine the qualifying species are followed by a simple table of the species identification (scientific and common name as used in NatureServe Explorer), the species conservation status and its weight, the number of species in the family, distinctiveness calculation, the BSI score and the total score for the project (at table end). Notes after the table indicate the species in the HUC that have been excluded and the reason for exclusion.

3 Results

Case Studies

Arkansas River

Location: Below Keystone Dam, Oklahoma

Problem: Habitat disturbed by operations of Keystone Dam.

Project Solution: Restore water quality, stream banks, and alluvial floodplains downstream from the dam.

HUC: 1110101

Table 1. G1 (highly imperiled, G2 (imperiled) and G3 (vulnerable) species with potential for species population recovery in the Arkansas River project area (assuming the project targets species needs). "Valu" is the assigned weight or calculated value of the metric term and Fam # is the number of species in the taxonomic Family.

Scientific name	Common name	Status	Valu	Fam #	Valu	Total
Macrochelys temminckii	Alligator snapping turtle	G3-4	4	2	0.5000	2.0000
Notropis girardi	Arkansas River shiner	G2	16	265	0.0038	0.0604
Macrhybopsis tetranema	Arkansas River speckled chub	G1	64	265	0.0038	0.2415
Total						2.3019

Note: Two plant species (Texas fescue, Oklahoma beardtongue) were excluded because of upland habitat needs.

Barataria Basin Barrier Island

Location: Mississippi River Delta southwest of New Orleans

Problem: Erosion of delta wetlands and barrier islands has degraded habitats

Project Solution: Construct barrier islands to restore island habitat and to encourage wetland habitat recovery.

HUC: 080903010.

Table 2. G1 (highly imperiled, G2 (imperiled) and G3 (vulnerable) species with potential for species population recovery in the Barataria Basin project area (assuming the project targets species needs). "Valu" is the assigned weight or calculated value of the metric term and Fam # is the number of species in the taxonomic Family.

Scientific name	Common name	Status	Valu	Fam #	Valu	Total
Charadrius melodus	Piping plover	G3	4	56	0.0179	0.0716
Atractosteous spatula	Alligator gar	G3-4	4	5	0.2000	0.8000
Carex decomposita	Cypress-knee sedge	G3	4	830	0.0012	0.0048
Fundulus jenkinsi	Saltmarsh topminnow	G3	4	36	0.0278	0.1112
Physalis angustifolia	Coast ground-cherry	G3-4	4	114	0.0088	0.0352
Schizachyrium maritimum	Gulf bluestem	G3-4	4	978	0.0010	0.0040
Total						1.0268

Notes. The manatee was not included because it is a visitor only (no significant population expansion likely). The area is not historic sea turtle nesting habitat (they are sighted offshore only).

Chautauqua Creek

Location: Chautauqua Creek, near Westfield New York.

Problem: A dam on Chautauqua Creek blocks fish movement to approximately 10 miles of river upstream.

Project Solution: Construct fish passage or dam removal to enable access of fish to the river above the dam.

HUC: 04120102

Table 3. G1 (highly imperiled, G2 (imperiled) and G3 (vulnerable) species with potential for species population recovery in the Chautauqua Creek project area (assuming the project targets species needs). "Valu" is the assigned weight or calculated value of the metric term and Fam # is the number of species in the taxonomic Family.

Scientific name	Common name	Status	Valu	Fam #	Valu	Total
Acipenser fulvescens	Lake sturgeon	G3-4	4	8	0.1250	0.5000
Clinostomus elongatus	Redside dace	G3-4	4	265	0.0038	0.0151
Epioblasma triquetra	Snuffbox	G3	4	290	0.0034	0.0136
Total						0.5287

Notes: The bald eagle, eastern sand darter, and mooneye are mentioned as project "targets", but all are G5 or G4 species.

Chesapeake Bay

Location: Chesapeake Bay of Maryland and Virginia.

Problem: Oyster-reef habitats are in decline and are now at a small percentage of historic levels.

Project Solution: Develop a bay-wide oyster restoration master plan to cover actions in both Maryland and Virginia.

HUC: 02060001(upper Chesapeake) and HUC 02080101 (lower Chesapeake).

Table 4. G1 (highly imperiled, G2 (imperiled) and G3 (vulnerable) species with potential for species population recovery in the Chesapeake Bay project area (assuming the project targets species needs). "Valu" is the assigned weight or calculated value of the metric term and Fam # is the number of species in the taxonomic Family.

Scientific name	Common name	Status	Valu	Fam #	Valu	Total
Acipenser brevirostrum	Shortnose sturgeon	G3	4	8	0.1250	0.5000
Acipenser oxyrinchus	Atlantic sturgeon	G3	4	8	0.1250	0.5000
Total						1.0000

Notes: Numerous species were excluded because of habitat requirements that did not match the intents of the project. These include hellbender and tidewater mucket, Long's bittercress, and swamp-pink (basically freshwater species) and seaside alder, cream tick-trefoil, Parker's pipewort, and seabeach knotweed (upland species). The explicit target of the project, the American Oyster, was not included because it is a G5 species. Others mentioned explicitly as positively affected (striped bass, bluefish, American oystercatcher) are also G5 species.

Chicago Ship and Sanitary Canal

The Location: The canal connects the Laurentian Great Lakes to the Mississippi River through the Chicago and Illinois rivers.

The Problem: Concern about the effects of nonnative Asian Carp (mostly bighead carp, *Hypophthalmichthys nobilis,* and silver carp, *Hypophthalmichthys molitrix*), led to construction of a temporary demonstration electric barrier to invasion of Lake Michigan in 2002. Asian carp inhabit large river and lakes where they may negatively affect native species.

Project Solution: Permanent construction and improvement of the existing barrier.

HUC: 04120200, 04080300, 04060200, 04090002, 04020300, and 04150200 (all of the five Great Lakes, and Lake St. Claire).

Table 5. G1 (highly imperiled, G2 (imperiled) and G3 (vulnerable) species with potential for species population recovery in the Chicago Ship and Sanitary Canal project area (assuming the project targets species needs). "Valu" is the assigned weight or calculated value of the metric term and Fam # is the number of species in the taxonomic Family.

Scientific name	Common name	Status	Valu	Fam #	Valu	Total
Charadrius melodus	Piping plover	G3	4	11	0.0909	0.3636
Acipenser fulvescens	Lake Sturgeon	G3-4	4	8	0.1250	0.5000
Coregonus kiyi	Kiyi	G3	4	38	0.0263	0.1053
Coregonus zenithicus	Shortjaw cisco	G3	4	38	0.0263	0.1053
Notropis anogenus	Pugnose shiner	G3	4	265	0.0038	0.0151
Coregonus nigripinnis	Blackfin cisco	G3	4	38	0.0263	0.1053
Villosa fabalis	Rayed bean	G2	16	290	0.0034	0.0544
Lampsilis abrupta	Pink mucket	G2	16	290	0.0034	0.0544
Epioblasma triquetra	Snuffbox	G3	4	290	0.0034	0.0136
Potamilis capax	Fat pocketbook	G1-2	64	290	0.0034	0.2176
Total						1.5346

Notes: All of the counted species consume foods in Great Lakes environments and may be directly or indirectly impacted by the carp through the food web. A number of G1-G3 species were excluded because their habitat was judged to be insignificantly affected by Asian Carp. A large number are terrestrial, including three snail species (Pleistocene catinella, Hubrict's vertigo, and deep-throat vertigo), 13 plant species (lakeside daisy, Hill's thisle, dune thistle, Ram's-head lady's-slipper, dwarf lake iris, pointed moonwort, little goblin moonwort, pale moonwort, prairie moonwort, rugulose grapefern, Laurentian bladderfern, auricled twayblade) and a reptile (eastern fox snake). The eastern prairie white-fringed orchid was excluded because it lives in wet prairies out of reach of the carp. Three species of freshwater mussels (salamander mussel, purple lliput, and tubercled blossom) were excluded because they live primarily in tributaries beyond significant carp impact. The deepwater pondsnail was excluded because it occurs only in remote inland lakes where it feeds on periphyton.

Columbia River

Location: Lower Columbia River near River mile 38, Julia Butler Hanson NWR

Problem: Fish passage in and out of wetlands bordering the river are now blocked by dikes. Endangered salmon species were specifically mentioned.

Project Solution: Install culverts and tide gates to allow fish access to 87 acres of wetlands, plant 210 acres of riparian area, and restore meanders of a tributary creek.

HUC: 17080003 (Lower Columbia-Clatskanie).

Table 6. G1 (highly imperiled, G2 (imperiled) and G3 (vulnerable) species with potential for species population recovery in the Columbia River project area (assuming the project targets species needs). "Valu" is the assigned weight or calculated value of the metric term and Fam # is the number of species in the taxonomic Family.

Scientific name	Common name	Status	Valu	Fam #	Valu	Total
Anodonta californiensis	California floater	G3	4	290	0.0034	0.0138
Acipenser medirostris	Green sturgeon	G3	4	8	0.1250	0.5000
Total						0.5138

Notes: One mammal (white-footed vole) and several plant species (tall bugbane, Oregon fleabane, loose-flower bluegrass, Hooker's bluegrass, bristly-stemmed sidalowea, and Nelson's sidalowea) were excluded because of upland habitat or temporary wetland requirements unlike the planned tidal wetlands. Asian water-milfoil was excluded because it is a nonnative species. Salmon were targeted by the project, but even though several populations of Columbia River salmon are protected under the ESA, no west coast salmon species is ranked lower than G5.

Duwamish and Green Rivers

Location: Near Seattle, Washington

Problem**:** Degraded estuarine fish habitat.

Project Solution: Construct ecosystem restoration features to improve salmonid nursery habitat through restoration.

HUC: 17110013(Duwamish).

Table 7. G1 (highly imperiled, G2 (imperiled) and G3 (vulnerable) species with potential for species population recovery in the Duwamish and Green Rivers project area (assuming the project targets species needs). "Valu" is the assigned weight or calculated value project are of the metric term and Fam # is the number of species in the taxonomic Family.

Scientific name	Common name	Status	Valu	Fam #	Valu	Total
Acipenser medirostris	Green sturgeon	G3	4	8	0.1250	0.5000
Rhinichthys sp. 4	Nooksack dace	G3	4	265	0.0038	0.0152
Salvelinus confluentus	Bull trout	G3	4	38	0.0263	0.1052
Total						0.6204

Notes: Two plant species (white meconella and Columbia white-top aster) were excluded because of upland habitat needs. Salmon were targeted but no west coast salmon species is ranked less than G5.

Everglades

Location: Southern Florida

Problem: Water diversion and water quality degradation threaten the integrity of Everglades National Park

Project Solution: Restore more natural hydrology and water quality to maintain Everglades habitats.

HUC: 03090201, 03090202, 03090203, 03090204, 03090205, 03090102, 03090101 (Everglades watershed units).

Table 8. G1 (highly imperiled, G2 (imperiled) and G3 (vulnerable) species with potential for species population recovery in the Everglades project areas (assuming the projects target species needs). "Valu" is the assigned weight or calculated value of the metric term and Fam # is the number of species in the taxonomic Family.

Scientific name	Common name	Status	Valu	Fam #	Valu	Total
Neofiber alleni	Round-tailed muskrat	G3	4	76	0.0134	0.0536
Trichechus manatus	West Indian manatee	G2	16	1	1.0000	16.0000
Patagioenas leucocephala	White-crowned pigeon	G3	4	12	0.0833	0.3332
Crocodylus acutus -	American crocodile	G2	16	1	1.0000	16.0000
Ctenogobius stigmaturus	Spottail goby	G2	16	24	0.0417	0.6672
Gambusia rhizophorae	Mangrove gambusia	G3	4	14	0.0714	0.2857
Rivulus marmoratus	Mangrove rivulus	G3	4	1	1.0000	4.0000
Crangonyx grandimanus	Florida cave amphipod	G2-3	16	211	0.0047	0.0758
Crangonyx hobbsi	Hobb's cave amphipod	G2-3	16	211	0.0047	0.0758
Procanbarus milleri	Miami cave crayfish	G1	64	355	0.0028	0.1792
Villosa amygdala	Florida rainbow	G3	4	290	0.0034	0.0136
Bourreria cassinifolia	Smooth strongbark	G3	4	302	0.0033	0.0132
Brassia caudata	Spider orchid	G3-4	4	208	0.0048	0.0192
Cucurbita okeechobeensis	Okeechobee Gourd	G1	4	45	0.0222	0.0888
Galeandra bicarinata	An endemic orchid	G1	64	208	0.0045	0.2880
Halophila johnsonii -	Johnson's sea-grass	G2	16	11	0.0909	1.4544
Hypericum edisonianum	Edison's ascyrum	G2	16	56	0.0179	0.2857
Lepanthopsis melanantha	Tiny orchid	G3-4	4	208	0.0048	0.0192
Oncidium floridanum	Florida orchid	G2	16	208	0.0048	0.0768
Polyradicion lindenii	Ghost Orchid	G2-4	16	208	0.0048	0.0868
Rhynchospora floridensis	Florida whitetop	G3	4	830	0.0012	0.0048
Roystonea elata	Florida royal palm	G2-3	16	32	0.0313	0.5000
Swietenia mahagoni	West Indian Mahogany	G3-4	4	1	1.0000	4.0000
Total						44.5210

Notes: Several plant and one bird species on island hammocks were included because of possible fire protection improvement by more reliable water supply. Several species of subterranean aquatic species are included because of more dependable groundwater supply. Many G1-3 species that inhabit uplands and ocean shores were excluded because the species are out of program reach These include 3 mammals (Florida deermouse, Rafineque's big-eared bat, Florida bonneted bat), 3 birds (piping plover, Florida scrub jay, Bachman's sparrow), 9 reptiles (loggerhead, green turtle, hawksbill, Kemp's Ridley sea turtle, leatherback, gopher turtle, Florida scrub lizard, eastern Indigo snake, rim rock crowned snake), one amphibian (Carolina gopher frog), two terrestrial snails (crenulate horn and truncate urocoptid), and 53 vascular plants (Wrights flowering fern, holly-leaf fern, Eaton's spike-moss, Hattie Bauer's halberd fern, bracted colicroot, Blodgett's wild mercury, four-petal pawpaw, Carter's orchid, many-flower grass-pink, Garber's spurge, Florida jointgrass, large-flowered rosemary, christmasberry, Lakela's mint, two-spike crabgrass, cape sable throughwort, pineland poinsettia, pineland milk pea, Small's milkpea, Galeandra bicarinata, coastal sandune vervain, Tampa vervain, holywood lignumvitae, fragrant prickly-apple, Simpson's prickly-apple, wild potato morning-glory, Rockland morning-glory, pineland jacquemontia, reclined clustervine, nodding pinweed, pine pinweed, sand flax, fall-flowering ixia, burrowing four-o'clock, cutthroat grass, tiny polygala, Bahama shadow-witch, giant orchid, Bahama sachsia, scrub bluestem, Havana skullcap, Everglade key pencil-flower, variegated orchid, Florida key nosebum, Florida gamagrass, Mexican vanilla, rain lily, pinewood's bluestem, Chapman's skeletongrass, flowering southern morning-glory, pygmy fringetree, Chrysopsis highlandsensis,Ashe's savory).

Fox Island

Location: Mississippi River Island in Missouri.

Problem: Pool construction contributed to reduced bottomland forest and wetlands which limits species recovery

Project Solution: Rehabilitate about 2000 acres of floodplain forest, wet prairie and other wetlands with emphasis on migratory and wading bird habitat.

HUC: 07110001

Table 9. G1 (highly imperiled), G2 (imperiled) and G3 (vulerable) species with potential for species population recovery in the Fox Island project area (assuming the project targets species needs)."Valu" is the assigned weight or calculated value of the metric term and Fam # is the number of species in the taxonomic Family.

Scientific name	Common name	Status	Valu	Fam #	Valu	Total
Clonophis kirtlandii	Kirtland's snake	G2	16	113	0.0088	0.1408
Agalinis auriculata	Earleaf false foxglove	G3	4	706	0.0014	0.0056
Agalinis skinneriana	Pale False Foxglove	G3-4	4	706	0.0014	0.0056
Asclepias meadii	Mead's Milkweed	G2	16	117	0.0085	0.1360
Platanthera leucophaea	Eastern prairie white-fringed orchid	G2-3	16	208	0.0048	0.0768
Total						0.3648

Notes: Based on the habitat improvement information provided and characteristics of the Mississippi river, several G1-3 species found in the HUC were excluded because they are upland cave inhabitants (Indiana myotis) or require different aquatic or terrestrial habitats from that provided by the project (western sand darter, lake sturgeon, blue sucker, Alabama shad, Topeka shiner, spectacle case, Higgins eye, sheepnose, fat pocketbook, winged mapleleaf, and buffalo clover). Other targeted species included lesser scaup, smallmouth buffalo, river otter, paddlefish, and western chorus frog, all of which are G4 or G5 species. The pallid sturgeon also was targeted but excluded because it did not show up in the HUC for Fox Island or in any upper Mississippi HUC other than just above the confluence with the Missouri River (HUC 0711009 about 100 miles to the south). The much higher natural turbidity of the Missouri and lower Mississippi, probably required by the sturgeon based on its coloration, is a possible explanation for why the pallid sturgeon does not extend far north of the confluence. The range of two other large and unique G1-3 species—the alligator snapping turtle and alligator gar--do not extend into the upper Mississippi river.

Fourche Bayou

Location: Fourche Creek, Arkansas (west-central Arkansas)

Problem: The project is for flood risk management but environmental protection is needed.

Project Solution: Gain funding for protection of wetland habitat from urban sprawl.

HUC: 11110206 (Fourche-LeFav).

Table 10. G1 (highly imperiled), G2 (imperiled), and G3 (vulnerable) species with potential for species population recovery in the Fourche Creek project area (assuming the project targets species needs). "Valu" is the assigned weight or calculated value of the metric term and Fam # is the number of species in the taxonomic Family.

Scientific name	Common name	Status	Valu	Fam #	Valu	Total
Eleocharis wolfii	Wolf's spikerush	G3-4	4	830	0.0012	0.0048
Ptilimnium nodosum	Harperella	G2	16	335	0.0030	0.0480
Vernonia lettermannii	Narrowleaf ironweed	G3	4	2298	0.0004	0.0016
Total						0.0544

Notes: A number of G1-G3 species were excluded because they require riverine or terrestrial habitats instead of the wetland habitat described in the report. These include one bird (red cockaded woodpecker), 2 salamanders (Rich Mountain, Fourche Mountain), 2 fish (Kiamichi shiner, longnose darter), 6 freshwater mussels (Ouchita kidneyshell, scaleshell, southern hickorynut, sandbank pocketbook, purple lilliput, Ouachita creekshell) and 7 plant species (Ozark cornsalad, Ouachita bluet, southern lady's-slipper, Hubrict's slimpod, Ouachita leadplant, rivergrass, and waterfall's sedge).

Henderson Lake

Location: Atchafalaya Basin, Louisiana.

Problem: The Atchafalaya Floodway flood conveyance and environmental properties are degraded.

Project Solution: Acquisition of real estate in the lower Atchafalaya Floodway for flood control and environmental protection purposes.

HUC: 08080101 (Atchafalaya).

Table 11. G1 (highly imperiled), G2 (imperiled), and G3 (vulnerable) species with potential for species population recovery in the Henderson Lake project area (assuming the project targets species needs). "Valu" is the assigned weight or calculated value of the metric term and Fam # is the number of species in the taxonomic Family.

Scientific name	Common name	Status	Valu	Fam #	Valu	Total
Atractosteous spatula	Alligator gar	G3-4	4	5	0.2000	0.8000
Fundulus jenkensi	Saltmarsh killifish	G3	4	36	0.0278	0.1112
Scaphirhynchus albus	Pallid sturgeon	G2	16	8	0.1250	0.5000
Macrochelys temminckii	Alligator snapping turtle	G3-4	4	2	0.0038	2.0000
Total						3.4112

Notes: A bird (piping plover) and 3 upland plant species (croomia, coast ground-cherry, nodding pogonia) were excluded based on the wetland habitat description.

Kissimmee River

Location: Central Florida

Problem: The "natural lake environment" and recreation are degraded by exotic aquatic plants.

Project Solution: Eliminate/reduce exotic plants.

HUC: 030903101 (Kissimmee)

Table 12. G1 (highly imperiled), G2 (imperiled), and G3 (vulnerable) species with potential for species population recovery in the Kissemmee River project area (assuming the project targets species needs). "Valu" is the assigned weight or calculated value of the metric term and Fam # is the number of species in the taxonomic Family.

Scientific name	Common name	Status	Valu	Fam #	Valu	Total
Neofiber alleni	Round-tailed muskrat	G3	4	76	0.0134	0.0536
Carex chapmanii	Chapman's sedge	G3	4	830	0.0012	0.0048
Hartwrightia floridana	Florida hartwrightia	G2	16	2298	0.0004	0.0064
Hypericum edisonianum	Edison's ascyrum	G2	16	56	0.0175	0.2800
Illicium parviflorum	Yellow anisetree	G2	16	2	0.5000	8.0000
Najas filifolia	Narrowleaf naiad	G1	64	6	0.1667	10.6688
Nemastylis floridana	Fall-flowering ixia	G2	16	71	0.0141	0.2256
Platanthera integra	Yellow fringeless orchid	G3-4	4	208	0.0048	0. 0192
Salix floridana	Florida willow	G2	16	91	0.0110	0.1760
Total						19.4344

Notes: A large number of G1-3 species were excluded because they are not likely to respond positively to the project, usually because of upland terrestrial requirements. Some in fact may be harmed by the project if they have colonized areas that were once regularly flooded. The species include 2 mammals (Florida deermouse, Rafinesque's big-eared bat), 3 birds (red-cockaded woodpecker, Florida scrubjay, Bachman's sparrow), 4 reptiles (Florida scrub lizard, sand skink, eastern indigo snake, short-tailed snake), 1 amphibian (Carolina gopher frog), 1 mollusk (ridge scrubsnail) and 33 vascular plants (pinewoods bluestem, Florida lady's-nightcap, many-flower grass-pink, sand butterfly-pea, pygmy fringetree, Chrysopsis highlandsensis, Ashe's savory, pigeon wings, Florida jointgrass, shortleaf rosemary, Avon Park rabbit-bells, yellow scrub balm, scrub mint, wedgeleaf button-snakeroot, Euphorbia resescens, Chapman's skeletongrass, highlands scrub St. John's-wort, nodding pinweed, Florida gayfeather, Florida milkvine, Florida bear-grass, cutthroat grass, Lewton's polygala, wireweed, Small's jointweed, scrub plum, giant orchid, Rhyncospora megaplumosa, scrub bluestem, flowering southern morning-glory, wide-leaf warea, Carter's mustard, and scrub ziziphus).

Lake Chautauqua

Location: Southwestern New York.

Problem: The "natural lake environment" and recreation are degraded by exotic aquatic plants.

Project Solution: Eliminate/reduce exotic plants.

HUC: 0501002 (Conewango)

Table 13. G1 (highly imperiled,) G2 (imperiled) and G3 (vulnerable) species with potential for species population recovery in the Lake Chautauqua project area (assuming the project targets species needs). "Valu" is the assigned weight or calculated value of the metric term and Fam # is the number of species in the taxonomic Family.

Scientific name	Common name	Status	Valu	Fam #	Valu	Total
Total						0

Notes: A number of G1-G3 species were excluded because none of them inhabited the lake historically and would not respond to lake restoration as proposed. These include four freshwater mussels that inhabit rivers or wave washed shores (tubercled blossom, rayed beam, clubshell, Ohio pebblesnail), three riverine fish species (Ohio lamprey, mountain brook lamprey, and redside dace), and one spring-fed bog plant (bog bluegrass).

Napa River Salt Marsh

Location: Northern San Francisco Bay, California

Problem: Estuarine fish dependency on wetlands is impacted by loss of marginal wetlands.

Project Solution: Protect and restore wetlands to promote estuarine fish recovery.

HUC: 18050001(Napa River).

Table 14. G1 (highly imperiled, G2 (imperiled) and G3 (vulnerable) species with potential for species population recovery in the Napa River Salt Marsh project area (assuming the project targets needs). "Valu" is the assigned weight or calculated value of the metric term and Fam # is the number of species in the taxonomic Family.

Scientific name	Common name	Status	Valu	Fam #	Valu	Total
Reithrodontomys raviventris	Salt marsh harvest mouse	G1-2	64	76	0.0132	0.8448
Acipenser medirostris	Green sturgeon	G3	4	8	0.1250	0.5000
Eucyclogobius newberryi	Tidewater goby	G3	4	24	0.0417	0.1668
Hypomesus transpacificus	Delta smelt	G1	64	7	0.1429	9.1456
Polygonum marinense	Marin knotweed	G1	64	375	0.0027	0.2728
Rhynchospora californica	California beakrush	G1	64	830	0.0012	0.0768
Suaeda californica	California sea-bite	G1	64	148	0.0068	0.4352
Symphyotrichum lentum	Suisun marsh aster	G2	16	2298	0.0004	0.0064
Total						11.4484

Notes: Numerous species were excluded because they require inland terrestrial and aquatic habitat. These include 1 bird (tricolored blackbird), 1 reptile (western pond turtle), 3 amphibians (foothill yellow-legged frog, California red-legged frog, California tiger salamander), 3 fish (hardhead, splittail, sacremento perch), 2 mollusks (mimic tryonia, marin Hesperian), 3 crustaceans (vernal pool fairy shrimp, Calasellus californicus [an isopod], California freshwater shrimp), and 50 vascular plants (bentflower fiddleneck, Alameda Manzanita, marsh sandwort, Napa milkvetch, San Joaquin saltbush, bakers blennosperma, Tiburon mariposa lily, small-flowered calycadenia, Rincon ridge ceanothus, Calistoga ceanothus, Napa ceanothus, Sonoma ceanothus, Sonoma spineflower, Franciscan thistle, Presidio clarkia, round-head blue-eye Mary, San Francisco collinsia, yellow larkspur, western leatherwood, dwarf downingia, narrowleaf fleabane, largeleaf filaree, fragran fritillary, dark-eyed gilia, Diablo rockrose, two-carpel dwarf-flax, Marin western flax, Napa western flax, Loma Prieta scurfpea, Santa Cruz tarplant, Santa Rosa oceanspray, northern California black walnut, beach layla, Colusa tidy-tips, false Venus'-looking-glass, San Francisco lessingia, Mason's lilaeopsis, Sebastopol meadfoam, Jepson's desert-trumpets, Cob Mountain lupine, white meconella, marsh silver-puffs, Marin County navarretia, white-rayed pentachaeta, Calistoga popcorn-flower, north coast false semaphore grass, Napa bluegrass, Chaparral grounsel, Thoma's microseris, Tomalpais streptanthus, Tiburon jewelflower, and San Francisco owl's-clover). In addition to salt marsh harvest mouse and delta smelt, the project targets clapper rail, black rail, song sparrow, western burrowing owl, Chinook salmon, and steelhead trout. All but the first two species are G4-5 species.

Niagara River

Location: Niagara River at Strawberry Island near Buffalo, NY

Problem: Fish abundances apparently limited by habitat degradation.

Project Solution: Improve limiting habitat to increase fish abundances by restoring stream flow through dam removal.

HUC: 04120104 (Niagara).

Table 15. G1 (highly imperiled), G2 (imperiled), and G3 (vulnerable) species with potential for species population recovery in the Niagara River project area (assuming the project targets species needs). "Valu" is the assigned weight or calculated value of the metric term and Fam # is the number of species in the taxonomic Family.

Scientific name	Common name	Status	Valu	Fam #	Valu	Total
Acipenser fulvescens	Lake sturgeon	G3-4	4	8	0.1250	0.5000
Lampsilis abrupta	Pink mucket	G2	16	290	0.0034	0.0544
Epioblasma triquetra	Snuffbox	G3	4	290	0.0034	0.0136
Potamilis capax	Fat pocketbook	G1-2	64	290	0.0034	0.2176
Total						0.7856

Notes: A prairie wetland species (eastern eastern prairie white-fringed orchid) and a riverine fish (redside dace) were excluded because their habitat needs are incompatible with the proposed restoration action. The project targeted the bald eagle (G5), common tern (G5), American bittern (G4), Henslow's sparrow (G4), northern harrier (G5), longear sunfish (G5), muskellunge (G5), northern pike (G5), smallmouth bass (G5) and the eastern sand darter, which is a subspecies of a G5 species. None were included because of their generally secure to secure status.

Ohio River Basin

Location: Ohio River from Pittsburg to Mississippi River

Problem: Degradation of river and floodplain ecosystems over decades of alteration

Project Solution: The program plan guides project connection, expansion and restoration of river and floodplain habitats degraded due to construction and operation of the navigation system.

HUC: 50140206, 50140204, 50140202, 50140201, 50190203, 05090201, 05090101, 05030202, 05030101, 05030106 (along the Ohio River).

Table 16. G1 (highly imperiled), G2 (imperiled) and G3 (vulnerable) species with potential for species population recovery in the project areas of the Ohio River and its floodplain (assuming the projects target species needs). "Valu" is the assigned weight or calculated value of the metric term and Fam # is the number of species in the taxonomic Family.

Scientific name	Common name	Status	Valu	Fam #	Valu	Total
Clonophis kirtlandii	Kirtland's snake	G2	16	113	0.0088	0.1408
Macrochelys temminckii	Alligator snapping turtle	G3-4	4	2	0.5000	2.0000
Cryptobranchus alleganiensus	Hellbender	G3-4	4	1	1.0000	4.0000
Acipenser fulvescens	Lake sturgeon	G3-4	4	8	0.1250	0.5000
Atractosteous spatula	Alligator gar	G3-4	4	5	0.2000	0.8000
Clinostomus elongates	Redside dace	G3-4	16	265	0.0038	0.0608
Crystallaria cincotta	Diamond darter	G1	64	207	0.0048	0.3070
Crystallaria asprella	Crystal darter	G3	4	207	0.0048	0.0192

Scientific name	Common name	Status	Valu	Fam #	Valu	Total
Cycleptis elongates	Blue sucker	G3-4	16	71	0.0141	0.2254
Ichthyomyzon bdellium	Ohio lamprey	G3-4	4	20	0.0500	0.2000
Percina macrocephala	Longhead darter	G3	4	207	0.0048	0.0192
Cyprogenia stegana	Fanshell	G1	64	290	0.0034	0.2176
Cumberlandia monodonta	Spectaclecase	G3	4	290	0.0034	0.0136
Epioblasma obliquata	Catspaw	G1	64	290	0.0034	0.2176
Fusconaia subrotunda	Longsolid	G3	4	290	0.0034	0.0136
Hemastena lata	Cracking pearlymussel	G1	64	290	0.0034	0.2176
Lampsilis abrupt	Pink mucket	G2	16	290	0.0034	0.0544
Lasmigona subviridis	Green floater	G3	4	290	0.0034	0.0136
Leptodea leptodon	Scaleshell	G1-2	64	290	0.0034	0.2176
Obovaria refusa	Ring pink	G1	64	290	0.0034	0.2176
Plethobasus cicatrocosis	White wartyback	G1	64	290	0.0034	0.2176
Plethobasus cooperianus	Orangefoot pimpleback	G3	4	290	0.0034	0.0136
Plethobasus cyphyus	Sheepnose	G1	64	290	0.0034	0.2176
Pluerobema clava	Clubshell	G2	16	290	0.0034	0.0544
Pluerobema plenum	Rough pigfoot	G1	64	290	0.0034	0.2176
Pluerobema rubrum	Pyramid pigtoe	G2-3	16	290	0.0034	0.0544
Potamilis capax	Fat pocketbook	G1-2	64	290	0.0034	0.2176
Quadrula cylindrical	Rabbitsfoot	G3-4	64	290	0.0034	0.2176
Quadrula fragosa	Winged mapleleaf	G1	64	290	0.0034	0.2176
Simpsonaias ambigua	Salamander mussel	G3	4	290	0.0034	0.0136
Villosa fabalis	Rayed bean	G2	16	290	0.0034	0.0544
Lithasia armigera	Armored rocksnail	G3-4	4	147	0.0068	0.0272
Lithasia geniculata	Ornate rocksnail	G3	4	147	0.0068	0.0272
Orconectes pardolotis	Leopard crayfish	G1	64	355	0.0028	0.1792
Amorpha nitens	Shining indigobush	G3	4	1136	0.0009	0.0035
Carex decomposita	Cypress-knee sedge	G3	4	830	0.0012	0.0048
Crataegus pennsylvanica	Pennsylvania hawthorn	G3	4	662	0.0015	0.0060
Eleocharis wolfii	Wolf's spikerush	G3-4	4	830	0.0012	0.0048
Hypericum adpressum	Creeping St. John's-wort	G3	4	69	0.0145	0.0580
Lysimachia fraseri	Fraser's loosestrife	G3	4	90	0.0111	0.0444
Potamogeton tenneseensis	Tennesee pondweed	G2	16	35	0.0286	0.4571
Sida hermaphrodia	Virginia mallow	G3	4	190	0.0053	0.0211
Silene ovate	Ovate catchfly	G3	4	243	0.0041	0.0165
Vitis rupestris	Rock grape	G3	4	23	0.0370	0.1480

Scientific name	Common name	Status	Valu	Fam #	Valu	Total
Total						12.0068

Notes: A number of upland terrestrial plants and animals were excluded because they are not associated with lower terrace floodplain areas that would be addressed by this project (Allegheny woodrat, Southeastern myotis, Rafinesque's big-eared bat, gray myotis, Indiana myotis, eastern small-footed myotis, Bachman's sparrow, green salamander, Maryland glyph, Appalachian bugbane, Price's potato-bean, French's shootingstar, southern lady's-slipper, Tennessee leafcup, tall larkspur, rock skullcap, juniper sedge, whorled horse-balm, earleaf false foxglove, buffalo clover, running buffalo clover, trailing tick-trefoil, Canby's mountain-lover, cutleaf meadow-parsnip). Mountain brook lamprey, popeye shiner, northern madtom, Indiana crayfish, Crittenden crayfish, and Bousfield's amphipod, and a subterranean isopod were excluded because they are limited to smaller river tributaries. Among the many freshwater mussels that occur in the HUCs only the purple Lilliput was excluded because it is not associated with large rivers. Other mussels seem to prefer medium to small rivers, but are also encountered in the records of large rivers, including the Ohio.

Red Mill Pond

Location: Headwaters of Little Calumet River near Gary Indiana.

Problem: Notching of a dangerous dam will reduce water table that affects a nature preserve

Project Solution: Restore water level, maintain about 12 acres of wetlands, remove nonnative plant species, and plant native plant species.

HUC: 04040001 (Little Calumet-Galien)

Table 17. G1 (highly imperiled), G2 (imperiled), and G3 (vulnerable) species with potential for species population recovery in the Red Mill Pond project area (assuming the project targets species needs). "Valu" is the assigned weight or calculated value of the metric term and Fam # is the number of species in the taxonomic Family.

Scientific name	Common name	Status	Valu	Fam #	Valu	Total
Agalinis skinneriana	Pale false foxglove	G3-4	4	706	0.0014	0.0057
Eleocharis wolfii	Wolf's spikerush	G3-4	4	830	0.0011	0.0044
Hypericum adpressum	Creeping St. John's-wort	G3	4	56	0.0179	0.0714
Platanthera leucophaea	Eastern prairie white-fringed orchid	G2-3	16	208	0.0048	0.0769
Poa paludigena	Bog bluegrass	G3	4	978	0.0010	0.0041
Schoenoplectus hallii	Hall's bulrush	G2-3	16	830	0.0012	0.0193
Clonophis kirtlandii	Kirtland's snake	G2	16	113	0.0088	0.1408
Total						0.3226

Notes: Several animal and plant species were excluded because their terrestrial, beach, or riverine habitat needs are not satisfied by the project. These include the Indiana myotis, piping plover, popeye shiner, lake sturgeon, Fanshell, earleaf false foxglove, Hill's thistle, dune thistle, forked aster, American ginseng, small whorled pagonia, and prairie flameflower.

Rio Grande Riparian Corridor

Location: Near Albuquerque, New Mexico

Problem: Cottonwood dominated riparian habitat and nearby river and wetland habitat is degraded by existing flood control projects.

Project Solution: Remove non-native plant species, create wetlands and side channels, remove jetty jacks, and plant native species.

HUC: 31302020 (Rio Grande, Albuquerque).

Table 18. G1 (highly imperiled), G2 (imperiled), and G3 (vulnerable) species with potential for species population recovery in the Rio Grande Riparian Corridor project area (assuming the project targets species needs). "Valu" is the assigned weight or calculated value of the metric term and Fam # is the number of species in the taxonomic Family.

Scientific name	Common name	Status	Valu	Fam #	Valu	Total
Myotis occultus	Arizona myotis	G3-4	4	33	0.0303	0.1212
Gila pandora	Rio Grande Chub	G3	4	265	0.0038	0.0152
Hybognathus amarus	Rio Grande Silvery Minnow	G1	64	265	0.0038	0.2532
Macrhybopsis aestivalis	Speckled Chub	G3-4	4	265	0.0038	0.0152
Notropis jemezanus	Rio Grande Shiner	G3	4	265	0.0038	0.0152
Notropis simus	Bluntnose Shiner	G2	16	265	0.0038	0.0608
Catostomus plebeius	Rio Grande Sucker	G3-4	4	71	0.0411	0.1644
Total						0.6452

Notes: Arizona myotis was included because it may benefit from tree-cavity roosts resulting from riparian restoration. One species of isopod (Socorro isopod) and two species of spring snail (Chupadera springsnail, Socorro springsnail) were excluded because they never occurred in the project area. Several upland species were excluded, including the Desert pocket gopher, San Antonio bluestar, Santa Fe milkvetch, Organ Mountain Indian-paintbrush, Payson hiddenflower, Mogollon willowgrass, tall bitterweed, White Mountain groundsel, San Mateo penstemon, and dune unicorn-plant. The southwestern subspecies of the willow flycatcher was targeted by the project, but the species is generally secure (G4).

San Antonio River

Location: Southeast of San Antonio, Texas

Problem: An existing flood damage reduction project has degraded river and riparian habitat along 8 miles of the San Antonio River.

Project Solution: Restore native riparian and aquatic habitat along the river reach.

HUC: 12100301 (upper San Antonio River).

Table 19. G1 (highly imperiled, G2 (imperiled), and G3 (vulnerable) species with potential for species population recovery in the San Antonio River project area (assuming the project targets species needs). "Valu" is the assigned weight or calculated value of the metric term and Fam # is the number of species in the taxonomic Family.

Scientific name	Common name	Status	Valu	Fam #	Valu	Total
Micropterus treculii	Guadalupe bass	G3	4	31	0.0323	0.1292
Lampsilis bracteata	Texas Fatmucket	G1	64	290	0.0034	0.2176
Quadrula aurea	Golden orb	G1	64	290	0.0034	0.2176
Toxolasma mearnsi	Western lilliput	G2	16	290	0.0034	0.0544
Physostegia correllii	Correl's False dragon head	G2	16	372	0.0027	0.0432
Festuca versuta	Texas Fescue	G3	4	978	0.0010	0.0040
Tridens buckleyanus	Buckley's fluffgrass	G3	4	978	0.0010	0.0040
Total						0.6700

Notes: A number of G1-G3 species were excluded because habitat restoration proposed at the project is inappropriate. These include 3 species of aquatic blind cave fauna (widemouth blindcat, toothless blindcat, Comal blind salamander), 1 upland bird species (golden cheeked warbler), and 3 species of upland plants (Elmendorf's onion, sandhill woolly-white, and peachbush).

Sand Creek Wetland

Location: Saunders County, Nebraska.

Problem: Ninety five percent of local riparian wetlands have been lost.

Project Solution: Restore native wetlands.

HUC: 10200203 (Salt)

Table 20. G1 (highly imperiled), G2 (imperiled) and G3 (vulnerable) species with potential for species population recovery in the Sand Creek Wetland project area (assuming the project targets species needs). "Valu" is the assigned weight or calculated value of the metric term and Fam # is the number of species in the taxonomic Family.

Scientific name	Common name	Status	Valu	Fam #	Valu	Total
Platanthera praeclara	Western prairie white-fringed orchid	G3	4	208	0.0048	0.0192
Sistrurus catenatus	Massasauga	G3-4	4	19	0.0526	0.2105
Notropis topeka	Topeka Shiner	G3	4	265	0.0038	0.0151
Total						0.2448

Notes: The Piping plover was excluded because the project habitat is inappropriate for its needs.

Savannah River

Location: Near Savannah, Georgia in the Savannah River Estuary.

Problem: Tidal creek inflow from the river was restored by removing shoaling, but support of wood stork and other species has not been monitored for performance.

Project Solution: Monitor the project to assure that tidal river sources of detritus to the river are provided as planned.

HUC: 03060109 (Lower Savannah).

Table 21. G1 (highly imperiled), G2 (imperiled), and G3 (vulnerable) species with potential for species population recovery in the Savannah River project area (assuming the project targets species needs). "Valu" is the assigned weight or calculated value of the metric term and Fam # is the number of species in the taxonomic Family.

Scientific name	Common name	Status	Valu	Fam #	Valu	Total
Acipenser brevirostrum	Shortnose sturgeon	G3	4	8	0.1250	0.5000
Lindera melissifolia	Pondberry	G2-3	16	13	0.0769	1.2308
Litsea aestivalis	Pondspice	G3	4	13	0.0769	0.3077
Total						2.0385

Notes: Most G1-3 in the HUC are terrestrial, freshwater, or fully marine species (sea turtles, whales) that do not survive in the proposed habitat, only visit rarely, or are so remotely influenced by habitat functions that effects would be immeasurable. Excluded were 1 marine mammal (West Indies manatee), 1 terrestrial mammal (Rafinesque's big-eared bat), 2 terrestrial birds (red-cockaded woodpecker, Bachman's sparrow), 3 terrestrial reptiles (gopher tortoise, mimic glass lizard, southern hog-nosed snake), 2 terrestrial amphibians (Carolina gopher frog, frosted flatwoods salamander), 2 freshwater fish (robust redhorse, bluebarred pygmy sunfish), and 8 freshwater mussels (brook floater, pod lance, brother spike, Roanoke slabshell, yellow lampmussel, rayed pink fatmucket, and tidewater mucket), and 11 upland or pine-wetland plants (Sandhills milkvetch, Chapman's sedge, croomia, lupine surfpea, spoon-flower, yellow fringeless orchid, Hooker's milkwort, giant orchid, giant-spiral ladies' tresses, and Florida dropseed). The project targeted bald eagle (G5) and wood stork (G4), which are generally secure.

Scioto T-Dike (Ohio River)

Location: Ohio River near the mouth of the Scioto River.

Problem: Habitat condition in the Ohio River now limits river species during winter and high flows. This project is part of the Ohio River Ecosystem Restoration Program (see Ohio River Basin)

Project Solution: Implement a project to create shelters from the excessive velocity.

HUC: 05090103 (Little Scioto-Tygarts) and 05090201 (Brush-Whiteoak). Two HUCs were required because the project is on their shared boundary.

Table 22. G1 (highly imperiled), G2 (imperiled), and G3 (vulnerable) species with potential for species population recovery in the Scioto T-Dike project area (assuming the projec targets needs). "Valu" is the assigned weight or calculated value of the metric term and Fam # is the number of species in the taxonomic Family.

Scientific name	Common name	Status	Valu	Fam #	Valu	Total
Clonophis kirtlandii	Kirtland's snake	G2	16	113	0.0088	0.1408
Cryptobranchus alleganiensus	Hellbender	G3-4	4	1	1.0000	4.0000
Acipenser fulvescens	Lake sturgeon	G3-4	4	8	0.1250	0.5000
Atractosteous spatula	Alligator gar	G3-4	4	5	0.2000	0.8000
Crystallaria asprella	Crystal darter	G3	4	207	0.0048	0.0192
Crystallaria cincotta	Diamond darter	G1	64	207	0.0048	0.3070
Cycleptis elongates	Blue sucker	G3-4	16	71	0.0141	0.2254
Ichthyomyzon bdellium	Ohio lamprey	G3-4	4	21	0.0476	0.1905
Percina macrocephala	Longhead darter	G3	4	207	0.0048	0.0192
Cumberlandia monodonta	Spectaclecase	G3	4	290	0.0034	0.0136
Cyprogenia stegana	Fanshell	G1	64	290	0.0034	0.2176
Epioblasma obliquata	Catspaw	G1	64	290	0.0034	0.2176
Epioblasma triquetra	Snuffbox	G3	4	290	0.0034	0.0136
Fusconaia subrotunda	Longsolid	G3	4	290	0.0034	0.0136
Lampsilis abrupt	Pink mucket	G2	16	290	0.0034	0.0544
Plethobasus cicatrocosis	White wartyback	G1	64	290	0.0034	0.2176
Plethobasus cooperianus	Orangefoot pimpleback	G3	4	290	0.0034	0.0136
Plethobasus cyphyus	Sheepnose	G1	64	290	0.0034	0.2176
Pluerobema clava	Clubshell	G2	16	290	0.0034	0.0544
Pluerobema plenum	Rough pigfoot	G1	64	290	0.0034	0.2176
Pluerobema rubrum	Pyramid pigtoe	G2-3	16	290	0.0034	0.0544
Obovaria refusa	Ring pink	G1	64	290	0.0034	0.2176
Quadrula fragosa	Winged mapleleaf	G1	64	290	0.0034	0.2176
Quadrula cylindrical	Rabbitsfoot	G3-4	64	290	0.0034	0.2176
Hemastena lata	Cracking pearlymussel	G1	64	290	0.0034	0.2176
Leptodea leptodon	Scaleshell	G1-2	64	290	0.0034	0.2176
Simpsonaias ambigua	Salamander mussel	G3	4	290	0.0034	0.0136
Villosa fabalis	Rayed bean	G2	16	290	0.0034	0.0544
Eleocharis wolfii	Wolf's spikerush	G3-4	4	830	0.0012	0.0048
Sida hermaphrodia	Virginia mallow	G3	4	190	0.0053	0.0211
Total						8.4720

Notes: The project clearly provides for the needs of aquatic species in the mainstem Ohio River and not in peripheral wetland, terrestrial or tributary habitat. Upland terrestrial species were excluded (Allegheny woodrat, Rafinesque's big-eared bat, Indiana myotis, gray myotis, eastern small-footed myotis, Maryland glymph, French's shootingstar, running buffalo clover, southern lady's-slipper, rock skullcap, Canby's mountain-lover, cutleaf meadow-parsnip, juniper sedge, world horse-balm, and earleaf false foxglove). Several wetland plant species were also excluded (Wolf's spikerush and Virginia mallow) as was a tributary species (popeye shiner).

Snake River

Location: Jackson Hole, Wyoming

Problem: Fish and wildlife habitat is degraded by levee construction.

Project Solution: Restore stability of stream channel habitat; protect diversity of existing island habitat, and restore diversity, sustainability of degraded habitat.

HUC: 17040101 (Snake Headwaters).

Table 23. G1 (highly imperiled), G2 (imperiled), and G3 (vulnerable) species with potential for species population recovery in the Snake River project area (assuming the project targets species needs). "Valu" is the assigned weight or calculated value of the metric term and Fam # is the number of species in the taxonomic Family.

Scientific name	Common name	Status	Valu	Fam #	Valu	Total
Lepidomeda copei	Northern leatherside chub	G1-2	64	265	0.0038	0.2432
Stephanomeria fluminea	Teton wire-lettuce	G2	16	2298	0.0004	0.0070
Total						0.2502

Notes: Five upland plant species were excluded (railhead milkvetch, Wyoming tansymustard, thick-leafed whitlow-grass, rockcress draba, and Peyson's bladderpod). A subspecies of the snake river cutthroat trout (Oncorhynchus clarkii ssp. 2) is a target for the restoration action but, because the species is G4 and subspecies are not considered, it was excluded from the score. Whooping cranes and bald eagles are also mentioned as possible targets. Whooping cranes have not been identified in the watershed and were not included. The bald eagle is a G5 species.

Upper Mississippi River

Location: Minneapolis, MN to Melvin Price Locks and Dam

Problem: Fish and wildlife habitat is degraded by past lock and dam and levee construction.

Project Solution: Plan to restore floodplain habitat and connectivity for fish and wildlife.

HUC: 07110001, 07110004, 07110009, 07110009, 07080104, 07060001, 07060003, 07060005, 07040003, 07040001, 07040006, 07010206 (HUCs along the Mississippi River).

Table 24. G2 (highly imperiled, G2 (imperiled), and G3 (vulnerable) species with potential for species population recovery in the project areas along the Upper Mississippi River (assuming the projects target species needs). "Valu" is the assigned weight or calculated value of the metric term and Fam # is the number of species in the taxonomic Family.

Scientific name	Common name	Status	Valu	Fam #	Valu	Total
Clonophis kirtlandii	Kirtland's snake	G2	16	113	0.0088	0.1408
Sistrurus catenatus	Massasauga	G3-4	4	19	0.0526	0.2105
Acipenser fulvescens	Lake sturgeon	G3-4	4	8	0.1250	0.5000
Alosa alabamae	Alabama shad	G3	4	17	0.0588	0.2353
Ammocrypta clara	Western sand darter	G3	4	207	0.0048	0.0192
Atractosteous spatula	Alligator gar	G3-4	4	5	0.2000	0.8000
Clinostomus elongates	Redside dace	G3-4	16	265	0.0038	0.0608
Crystallaria asprella	Crystal darter	G3	4	207	0.0048	0.0192
Cycleptis elongates	Blue sucker	G3-4	16	71	0.0141	0.2254
Scaphirhynchus albus	Pallid sturgeon	G2	16	8	0.1250	2.0000
Cumberlandia monodonta	Spectaclecase	G3	4	290	0.0034	0.0136
Epioblasma triquetra	Snuffbox	G3	4	290	0.0034	0.0136
Lampsilis higginsii	Higgins eye	G1	64	290	0.0034	0.2176
Leptodea leptodon	Scaleshell	G1-2	64	290	0.0034	0.2176
Plethobasus cyphyus	Sheepnose	G1	64	290	0.0034	0.2176
Potamilis capax	Fat pocketbook	G1-2	64	290	0.0034	0.2176
Quadrula fragosa	Winged mapleleaf	G1	64	290	0.0034	0.2176
Simpsonaias ambigua	Salamander mussel	G3	4	290	0.0034	0.0136
Villosa fabalis	Rayed bean	G2	16	290	0.0034	0.0544
Agalinis auriculata	Earleaf false foxglove	G3	4	706	0.0014	0.0056
Agalinis skinneriana	Pale False Foxglove	G3-4	4	706	0.0014	0.0056
Asclepias meadii	Mead's Milkweed	G2	16	117	0.0085	0.1360
Platanthera leucophaea	E. prairie white-fringed orchid	G2-3	16	208	0.0048	0.0768
Poa paludigena	Bog bluegrass	G3	4	978	0.0010	0.0041
Total						5.5225

Notes: The following species were not included because of small stream habitat requirements (Topeka shiner) or terrestrial requirements (Indiana myotis, gray myotis, briarton pleistocene snail, Hubrict's vertigo, bluff vertigo, Iowa Pleistocene vertigo, frigid ambersnail, buffalo clover, hills, thistle, decurrent false aster, kitten tails, clustered poppy-mallow, forked aster, American ginseng, shadowy goldenrod, marbled disc, prairie flameflower, nodding pogonia, northern wild monkshood, Iowa golden saxifrage, prairie bushclover, rugulose grapefern, prairie dunewort, ram's-head lady's-slipper, and Molenbrock's umbrella-sedge).

Factors Contributing To Project Ranking By the BSI

Because of the way it is constructed, the BSI ranked projects based on the number of G1-3 species, the level of species imperilment, and species distinctiveness. The results revealed relationships to underlying factors contributing to species number determined for a project site.

Table 25 summarizes the BSI and RSI scores and other information influencing score relationships.

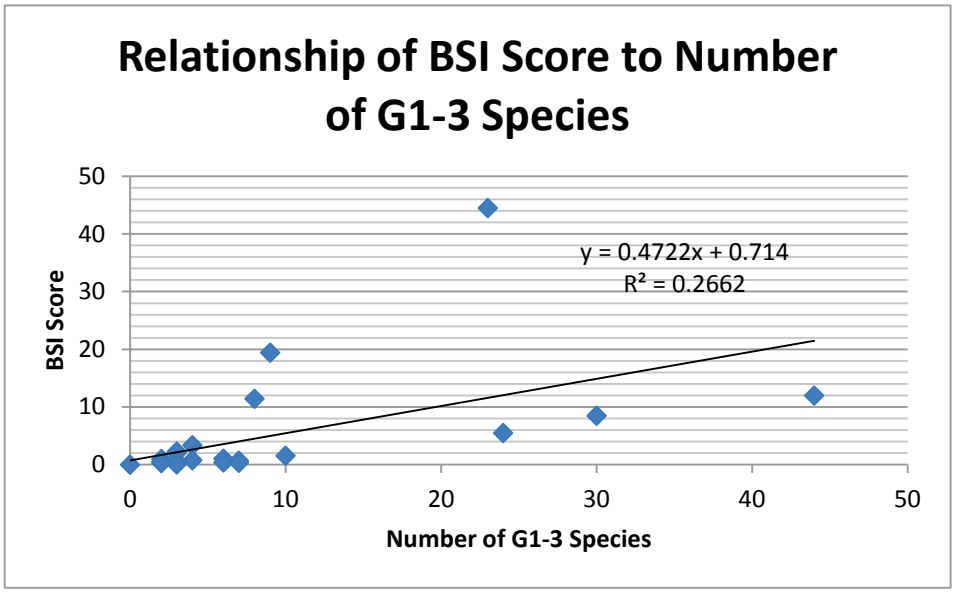
Table 25. Projects ranked by the BSI score and describe by habitat type, number of G1-3 species, number of G1-2 species, number of species from families with less than 11 species, sturgeon presence, latitude and, the RSI score now used for project ranking.

Project/Program	Habitat Type	BSI Score	G1-3 Sp. #	# G1-2 Sp.	Fam # <11	Sturgeon	Lat	RSI Score
Everglades	Large warm wetland/estuary	44.52	23	13	4	N	25.8	120
Kissimmee River	Medium-size warm river/wetland	19.43	9	6	2	N	28.3	125
Ohio River Basin	Large warm river/wetlands	12.01	44	18	4	Y	39.1	120
Napa Salt Marsh	Large cool-warm wetland/estuary	11.45	8	6	2	Y	38.3	100
Scioto T-Dike	Large warm river	8.47	30	17	3	Y	38.7	120
Upper Mississippi	Large cool-warm river/wetland	5.52	24	10	1	Y	43.0	120
Henderson Lake	Large warm river/wetland	3.41	4	1	3	Y	29.3	110
Arkansas River	Large warm river	2.30	3	2	1	N	36.2	81
Savannah River	Medium-size warm river/estuary	2.04	3	1	1	Y	32.1	113
Chicago Ship Canal	Large cool lakes	1.53	10	3	1	Y	41.9	90
Barataria Basin	Medium-size warm estuary	1.03	6	0	1	N	29.3	110
Chesapeake Bay	Large warm estuary	1.00	2	0	2	Y	39.0	95
Niagara River	Large cool river	0.79	4	2	1	Y	42.9	70
San Antonio River	Small warm river	0.67	7	4	0	N	29.4	81
Rio Grande	Medium-size warm river/wetland	0.65	7	2	0	N	35.1	86
Duwamish River	Medium-size cool river	0.62	3	0	1	Y	47.6	120
Chautauqua Creek	Small cool river	0.53	3	0	1	Y	42.3	80
Columbia River	Large cool estuary	0.51	2	0	1	Y	46.2	100
Fox Island	Large warm river/wetland	0.37	6	3	1	N	40.1	120
Red Mill Pond	Small cool wetland	0.32	7	3	0	N	41.6	70
Snake River	Medium-size cool-cold river	0.25	2	2	0	N	43.5	66
Sand Creek	Small warm wetland	0.24	3	0	0	N	41.3	55
Fourche Bayou	Small warm wetland	0.05	3	1	0	N	34.7	58
Lake Chautauqua	Medium-size warm lake	0	0	0	0	N	42.1	25

Number of G1-3 Species

As expected because of its construction, the number of species that are vulnerable to greatly imperiled was correlated with the BSI score. All of the sites with more than 20 G1-3 species were ranked among the top 25% (Table 25). More than a quarter of the variation in the BSI score was explained by the relationship (Figure 1). Major exceptions to the general trend were the Florida projects, explained in large part by a low number of freshwater mussels compared to other sites with a high number of G1-3 species. Freshwater mussels (Unionidae) contributed far more species than any other taxonomic Family. Other Families with disproportionate contribution include the minnows (Cyprinidae), Orchids (Orchidaceae), sedges (Cyperaceae) and sturgeons (Acipenseridae).

Figure 1. Relationship between the BSI score and number of G1-3 species at project sites.

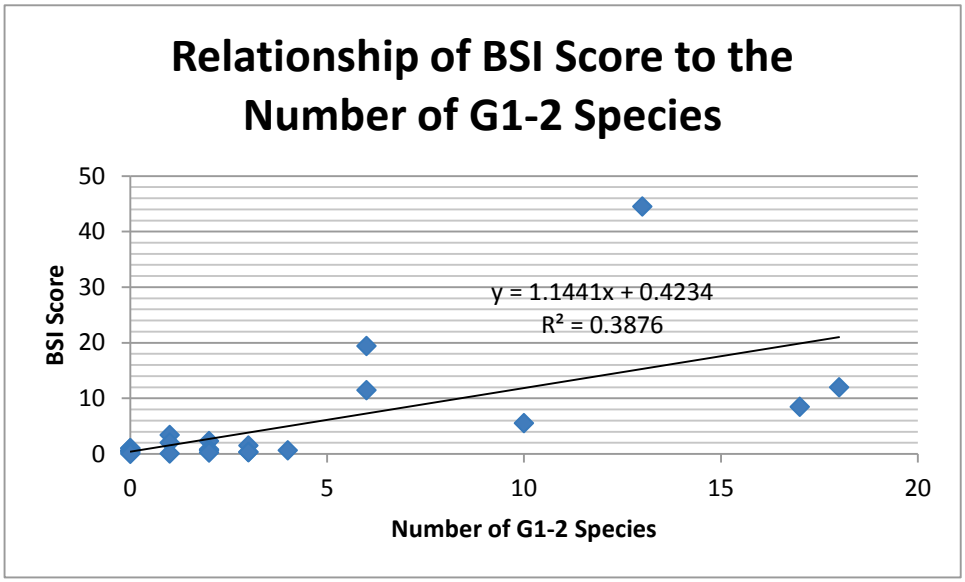


Conservation Status Weight

The greatly imperiled and imperiled species are weighted heavily (64 for G1 and 16 for G2). Because of the weights used, they contribute disproportionately much more to the score than vulnerable G3 species. G1 and G2 species composed 47% of the species but 90 % of the weight for all G1-3 species. Variation in the number of G1 and G2 species contribute more than a third of the variability in BSI rank (Figure 2). The top 5 project sites hosted 79% of the G1 species and 67% of the G1-2 species. Large river habitats contributed disproportionately to the total because of the numerous freshwater mussels that are G1-2 species. The Florida sites

were once again among the major exceptions to the general trend; other variables explained substantially more of their score.

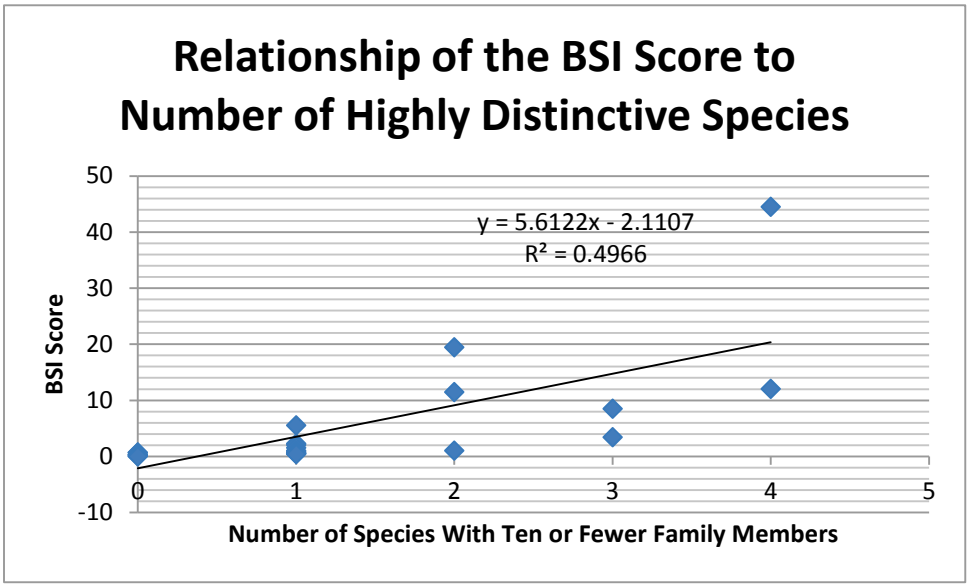
Figure 2. The relationship of the BSI scores to the number of highly weighted G1-2 species at the sites.



Species Distinctiveness

The number of species in the family contributes importantly to determining the high rank of projects. About half of the BSI score is explained by species distinctiveness (Figure 3). The only sites with highly distinctive species that had no more than one other U. S. member in its family were ranked in the top third (Arkansas River and above in Table 24). Distinctive species in Families of 8 or fewer American members were much more frequently encountered among the top ranked sites than the bottom half. Sturgeon were the most commonly encountered distinctive species (Table 24) and were the only distinctive species at most sites with only one distinctive species. Unlike sturgeon, most distinctive species at, or once at, the sampled sites are limited to southern ranges. Five of the species are in Florida at the northern edge of their families' tropical distribution. The exceptions to Families with southern distributions include the sturgeon and smelt Families. Distinctive species in this study also tend to be among the largest in their taxonomic classes. The exceptions are fish (delta smelt and mangrove rivulus). Most of the distinctive species in the case study are vertebrates. Plant species tend to be among the least distinctive in this study. The distinction of their species was a major contributor to the high BSI scores at the Everglades and Ohio River sites.

Figure 3. The relationship of the BSI Score to the number of highly distinctive species indicated by taxonic families with 10 or fewer family members.



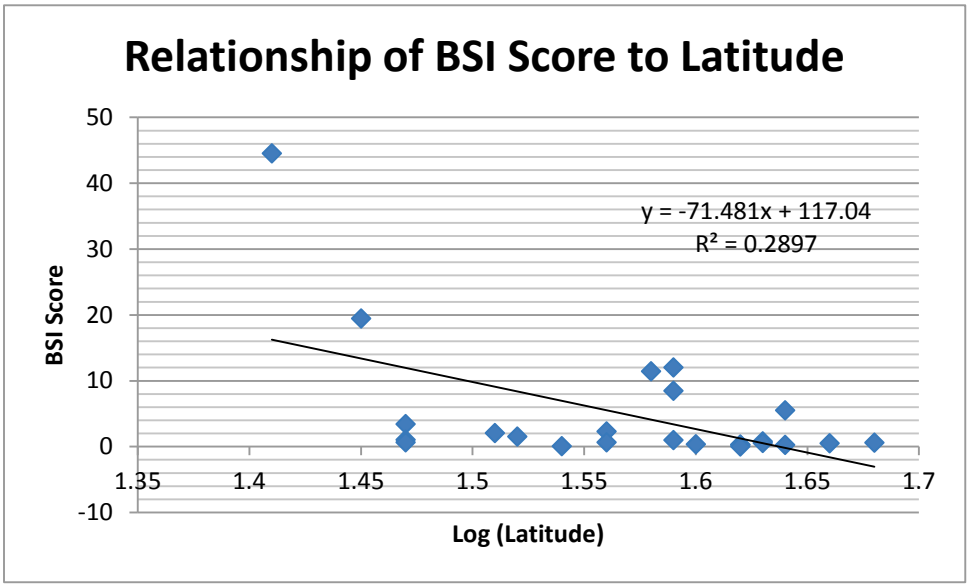
Based on the BSI, securing the viability of exceptionally rare and distinctive species contributes exceptionally to the security of the Nation's native biological heritage. When species are both imperiled and distinctive they contribute disproportionately to the BSI. Only one or two highly imperiled and distinctive species can elevate the score of a site to exceptional levels. A site with only one unique G1 species would have a BSI of 64.0, ranking it higher than the Everglades and the Ohio River, despite their much larger number of G1-3 species. The Everglades ranked especially high because of two G2 species that are the only members of their family in the United States. They alone comprised 72 % of the BSI score for the site. Two distinctive species of G1 and G2 status contributed 96 % to the Kissimmee River score.

Total Species, Latitude and Temperature

A number of underlying relationships contribute to explaining some of the observed patterns in the BSI score. If the fractions of G1-3 species and other effects were constant, the BSI would be expected to increase directly with the total number of species encountered in the area. But Master et al. (2000) demonstrated that the fraction of species at risk of extinction is not constant. It is lowest in the northern Midwest and increases to greatest fractions in southeastern and southwestern states. Nor is the total number of species constant. Because total species number increases along the same transects, the number of G1-3 species increases dramatically from lows in

the northern Midwest to highs in the Southwest and Southeast. This is consistent with the correlation of the BSI with the logarithm of latitude (Figure 4) and the prevalence of warm-water ecosystems among top ranked projects (Table 25). Only one of 7 cool- to cold-water ecosystems placed in the top half of BSI ranked sites.

Figure 4. The relationship of the logarithm of the BSI with project latitude.



Habitat Size and Diversity

Two related underlying influences on the BSI score are habitat size and habitat diversity. Many of the exceptions to the relationship of the BSI to latitude were in small- to medium-size habitats. Most of the sites ranked in the top half of projects were in large habitats. Sites ranked high in part because of their large geographical area and the diversity of habitats within those areas. Studies of species-area relationships repeatedly show that the number of discrete species found increases with geographical area but usually at a decreasing rate (Rosenzweig 1995). The connection of the BSI to geographical area sampled is indicated by the high species number and generally high BSI for the Everglades, Ohio River and Upper Mississippi programs (Table 24), which required several HUCs each to encompass them. Each of these programs includes a diversity of fully aquatic, wetland and other floodplain habitats. The Chicago Ship and Sanitary Canal barrier has potential for affecting species in multiple HUCs as well, having some influence on its rank in the upper half of all evaluated areas despite its northern location and cool–cold habitat. It also ranks lower than other large sites, which is consistent with the limitation of its effects to species in fully aquatic environments.

Connectivity

Another indirectly influential factor is the connectivity of a specific project habitat in the context of a much larger habitat. A local habitat in a larger but similar habitat context is more likely to have a high G1-3 count because of the general uniformity of conditions throughout all of the connecting habitat; e.g, Scioto T-Dike in the Ohio River and Niagara River in the Great Lakes (Table 25). An apparent exception at Fox Island project, which is in the Upper Mississippi River program area, has a low score compared to the Upper Mississippi River program because the project does not propose to restore mainstem river habitat where most of the G1-3 species reside. Numerous Mississippi River species were excluded because of that.

Range analysis reveals that many large-river fish, mollusk, and plant species were once widely distributed throughout the Mississippi River Basin, probably because of the high habitat similarity and connectivity along the river corridor. This study revealed the effect in the Ohio River where about 70% of its BSI and 68% its G1-3 species had been recorded in HUCs at Scioto T-Dike. The Niagara River BSI and Niagara River species made up about 50% and 40%, respectively, of the Great Lakes species despite a much smaller fraction of the total habitat area. Fragmentation of large habitats can result in reduced diversity, but the HUC data do not reflect that effect in general because occurrence documentation often occurred before the fragmentation occurred. In many cases the species no longer persist in the habitat.

BSI and RSI Ranking Comparison

A comparison of the BSI scores and the existing scores now used for ranking projects indicates some consistency between the two indices as well as substantial differences (Table 24). The highest and lowest five projects ranked by both metrics agreed well. The BSI ranking of the projects fit a logarithmic model (Figure 5). The RSI fit the same logarithmic model with greater variation. Half the variation (R^2=0.50) is explained by the relationship between the logarithms of the two metrics (Figure 6). The relationship appears to operate largely through the dominance of large habitats in the upper ranks of both approaches to scoring. Table 24 shows that all small habitats ranked in the lower half and all but two habitats in the upper half were large. Both metrics place emphasis on resource scarcity, but the BSI targets the scarcity of species and the RSI emphasizes habitat scarcity.

Figure 5. Logarithm models (fine lines) fit to the distribution of scores produced by the BSI and the RSI for 24 Corps projects.

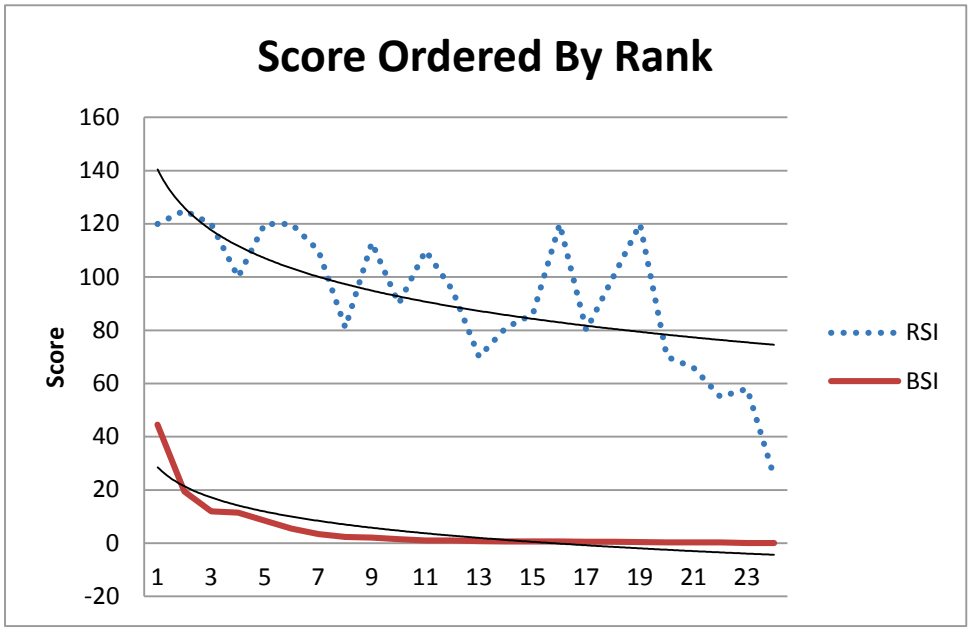
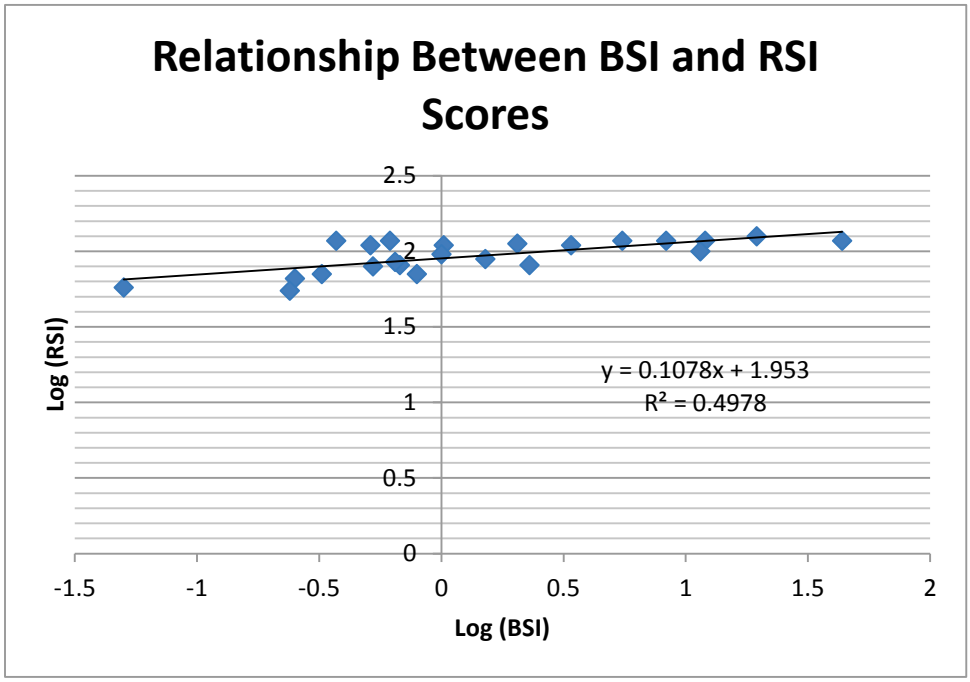


Figure 6. The relationship between log-transformed BSI and RSI scores.



Some of the positive relationship between the two metrics may derive from relationships between habitat scarcity and species scarcity. This appears to be the case for the subtropical habitats of the Florida sites and western estuarine wetlands off the mouth of the Napa River. Scarce habitats tend to be isolated and more likely to have species found nowhere else in the

United States. The differences between the BSI and RSI have to do with the much greater importance placed on habitat and connectivity by the RSI. Little emphasis is placed on “special status species” and the presence of one species counts as much as the presence of 100 in determining the score. In contrast, the BSI for ranking feasibility study only considers habitat to the extent that the project has any potential at all for restoring habitat for the G1-3 species (habitat plays a much larger role in calibrating a risk term, which is included for ranking construction projects). Lake Chautauqua is a particularly revealing project. It was ranked lowest by both metrics, but despite no G1-3 species, it was ranked positively by the RSI, giving some justification for funding a feasibility study. The BSI indicated no need for a feasibility study.

The BSI discriminates better than the RSI among the top projects and discriminates about as well as the RSI in the lower half of the rank. Half of the projects have RSI scores of 100 or more out of 125 points. This is a disadvantage when few new sites can be selected for feasibility study each year. The increasing similarity of the BSI scores among lower-ranked projects is caused largely by the low number of distinctive G1-3 species at the sites.

4 Discussion

BSI Application Assumptions and Issues

Assumptions

The following assumptions were made when applying the BSI in the case studies:

1. The BSI indicates ecosystem scarcity and value based on the scarcity of the species and the scarcity of ecosystem elements required to support the species.
2. Increased nonuse value of ecological resources is targeted by Corps planning policy guidance for ecological resource quality improvement using an ecosystem restoration and protection approach.
3. All species use value is irrelevant for ecosystem restoration plan formulation, including recreational, aesthetic and any other use benefit that can be acceptably valued in monetary terms using revealed preference techniques.
4. The security and distinctiveness terms and the weights used in the BSI are reasonable indicators of resource scarcity for resources with nonuse value. This assumption is defined by four subsidiary assumptions.

    a. NatureServe Explorer indication of global conservation status is an accurate general indicator of species viability and sustainability in the United States.

    b. The number of native American species that comprise the taxonomic Family is accurately represented in NatureServe Explorer and is a reasonably good indicator of the average number of unique traits contributing to the Nation's biological heritage.

    c. The choice of security status and distinctiveness weights generally reflects the relative scarcity of species attributes with respect to their long-term sustainability.

    d. The taxonomic information provided by NatureServe Explorer accurately represents the phylogenetic relationships of species and is updated quickly when changes occur.

5. The 8- digit HUC is a reasonably good geographical unit to use as a basis for determining that the species range extended into the project or program area.
6. The information provided in project reports adequately characterizes the type of habitat to be addressed and its geographical location.
7. Information provided by NatureServe Explorer on species distributions, ecology, and critical conservation needs accurately represents existing scientific knowledge.

The issues pertaining to these assumptions are described in the following sections.

The BSI Indicates Ecosystem Value

Corps policy interpretation has emphasized that the purpose of ecosystem restoration is to restore ecosystems; it is not to restore individual species. The emphasis is properly placed on a holistic approach that may imply to some that the entire ecosystem needs to be considered during restoration planning from a top-down perspective. The RSI translates this into a measure of the entire ecosystem's scarcity, including connectivity, to prioritize value. The BSI accomplishes the same thing from the perspective of the scarcest ecosystem elements, the species vulnerable to extinction, and the missing elements of ecosystems needed to support them.

The BSI approach will not restore the entire ecosystem. It can, however, partially restore and protect the least sustainable aspects of ecosystems nationally. Corps policy guidance (USACE 2000) recognizes that the scarcity of significant resources is the important consideration in assessing gross benefits. It also recognizes that most ecosystems cannot be entirely restored, which indicates a need for a measure of scarcity based on ecosystem parts rather than ecosystems as a whole. This is consistent with contemporary thinking of the community of restoration scientists, which is rapidly coming to a collective realization that ecosystems are largely novel and rarely if ever totally restorable (Hobbs et al. 2013). The RSI approach relies on old and outdated understanding of ecosystem structure and function.

The Nonuse Value Focus of Corps Planning Policy

If the interpretation of authority and policy guidance that guided BSI development is incorrect, the BSI may not fully represent restoration

benefits justifying project investment. The nonuse value focus of Corps ecosystem restoration authority and planning policy, and how it should be indicated, is not universally understood by all Corps planners. Unlike NED planning policy interpretation in specific manuals for navigation, flood risk management, and other NED purposes, the Corps has yet to develop a manual for the ecosystem restoration purpose. The development of a benefits metric required interpretation of ecosystem restoration project objectives, which indicate the anticipated benefits based on expected achievements.

Cole (2014 a, b, c) interpreted Corps project authority (Section 206, 1996 WRDA) and planning policy (USAC 2000) for ecosystem restoration projects directly from the original sources. To summarize, Congress authorized the Corps to use an aquatic ecosystem restoration and protection approach to environmental quality improvement with the stipulation that the improvement is cost effective and in the public interest. The restoration project outputs that justify the investment need to be ecological outputs (involving species communities in their supporting environments) of national interest and to be protected from consumptive (destructive) use. Output protection is open-ended, and therefore cross-generational. Protection must continue until that time Congress indicates otherwise. This is consistent with NEPA goals, which defines environmental quality broadly in terms of qualities that provide beneficial use of the environment while preserving important cultural and natural aspects of national heritage for present and future generations. Use of project outputs can be nonconsumptive, such as some forms of recreational enjoyment, but must not diminish the heritage-focused objective of the authority. Heritage value is nonuse value. Therefore, while not explicitly stated so in the law, Congress authorized the Corps to cost effectively improve and protect the quality of the nation's ecological heritage of demonstrated interest to the Nation for the benefit of present and future generations.

Corps planning guidance (USACE 2000) provides an institutional interpretation of the Congressional objective for environmental improvement using ecosystem restoration and protection measures, and how to demonstrate the public interest, formulate alternative plans, and indicate relative value of ecological outputs for plan evaluation, comparison and selection. In short, the Federal objective is to benefit the public through NED and NER while "damage to the environment is eliminated or avoided and important cultural and natural aspects of our

nation's heritage are preserved" (USACE 2000, page 2-1). The guidance explicitly indicates that NER benefits are separate from NED benefits, and that the nonuse value gained from heritage preservation must not be measured in monetary terms using the existing method, because it is unreliable (USACE 2000, Cole 2014a).

The Corps requires the outputs from ecosystem restoration projects to be measured in nonmonetary terms as a function of habitat improvement. Evidence of public interest indicates a public "demand" for an increased supply of "significant resources" that are scarce with respect to that demand. The ESA is a good example of both aspects. It establishes a public demand for increased output of unique species attributes of biodiversity that are presently unsustainable until they reach a sustainable state. Their level of sustainability is the indicator of relative scarcity. The BSI focuses on restoring and preserving the ecological heritage value indicated in the demand for and supply of specific elements of the Nation's native biodiversity.

The RSI interpretation of the authority and policy guidance accepts broader evidence of resource scarcity, which includes, in addition to species scarcity, the scarcity of habitat itself, including habitat connectivity, as an indicator of resource scarcity. Unlike the ESA and other law that commits to species sustainability, no law expresses a national commitment to recovering and sustaining habitat or ecosystems independent of their inhabitants. Thus there is no clear indication of a public "demand" for the preservation of habitats and ecosystems independent of their inhabitants. Without that demand, there is no values-based standard by which to measure their scarcity.

Wetland ecosystems and habitats are sometimes believed to be an exception based on Presidential policies on no net loss and wetland increase. But Executive order 11990 (Carter 1977), which is the basis of subsequent policies, highlighted the need to avoid, minimize and compensate for wetland loss because wetland services tended to be undervalued in environmental impact assessments required by the National Environmental Policy Act (NEPA). But it did not justify the policy based on wetland sustainability for its own sake. The executive order, and wetland legislation passed since then, justifies the actions based on the many different forms of wetland use value as well as the nonuse value of wetlands gained from the restoration of threatened and endangered species to a sustainable status.

Some may think the Corps "ecosystem restoration authority" is a sufficient indication of public demand for ecosystem sustainability, but the authority clearly indicates that ecosystem restoration and protection are complementary approaches to environmental quality improvement—not an objective. The objective is improvement of environmental quality of demonstrable public interest.

Thus there is little evidence in Federal official actions that the public demands more habitat based on a value independent of the nonuse value of species inhabitants. Habitat gains its value indirectly from the value of the species that use it. The mix of species and habitat indicators of scarcity in the RSI presents a challenge for plan and project comparison and selection because the relative scarcity of individual species attributes is not directly comparable to habitat scarcity. It complicates comparisons across plans within projects and projects within the program (see Cole 2014c for more discussion).

Exclusion of Use Value and Discounting

Use of the BSI assumes that the project benefit that justifies restoration investment is strictly limited to the gain in nonuse value. It excludes use value, which is measurable in monetary units using techniques that are now widely accepted in principle by economists (there may be technical difficulties in specific situations) (NRC 2005). Guidance requires all benefit from improved resource use (e.g., navigation and recreation improvements) to be measured in monetary terms. The relationship of the RSI to nonuse value is much less clear than the relationship of BSI to nonuse value because the habitat scarcity that contributes most to the index score is not clearly linked to a demand for habitat nonuse independent of the species inhabitants. If the assumption that the justifying benefits from ecosystem restoration are limited to nonuse value is incorrect, the BSI may improperly eliminate projects with acceptable restoration value. If it is correct, then the RSI is not clearly limited to nonuse value and may overestimate the benefits that justify investment for some projects.

The assumption that the justifying benefits should be limited to nonuse value is reinforced by Corps benefits discounting policy for ecosystem restoration projects (USACE 2000). Discounting of project benefits is limited by Corps guidance to the benefits measurable in monetary units. This is consistent with the intent for the benefits of use to be returned

largely to the investing generation, rather than to future generations. In contrast, the value added by ecosystem restoration projects is not discounted ((USACE 2000, E154); i.e., the discount rate is 0. This is consistent with a nonuse benefit that accrues equally to both present and future generations.

Resource Scarcity and Value

Nonuse value is assumed to be indicated by resource scarcity, which is indicated by their low abundance with respect to the public demand for their sustainability conveyed in the goal of the ESA. The identification of nonuse value indicated by the BSI depends on the degree to which the security and distinctiveness terms indicate resource scarcity reasonably well. Four aspects of this issue are separately addressed below and then compared to the RSI approach to scarcity and value.

Global security status

The basis of the security score for the species in a project study area depends largely on the global rank of species security from extinction captured in its conservation status rank. Because of the state of conservation data, conservation status categories are quite grossly defined in NatureServe Explorer. The accuracy of species assignment to a specific conservation status depends on the knowledge of species populations, including their long-term sustainability. Significant subjectivity remains in the assignment of status because of incomplete knowledge about species and population numbers, trends and threats. As a consequence, a species with a slight difference in estimated population occurrences—say 7 or 8 verses 5 or 6—is ranked significantly more secure in a G2 category than a G1 species with 5 or 6 populations. This is an unavoidable consequence of our rudimentary but rapidly advancing state of knowledge. Creating more categories at this time is not warranted but, as information improves, the status categories can be refined, making transition from one status to another less dramatic. This source of possible error is most important when the project scores are very similar, as many were among the low ranked projects in this study.

Distinctiveness

The number of American species in the taxonomic family is used to indicate distinctiveness in lieu of more precise genetic information

because that information is still too scarce to depend on. Based purely on a distinctiveness criterion, the global number of species in the family would be preferred. On the other hand, American species distinctiveness may relate more closely to the scarcity of ecological resources needed to sustain the American natural heritage that the Corps and other Federal agencies must focus on. Global estimates are much less reliable than American estimates. Except for well documented classes of species, global estimates rarely indicate a precise number of species within families. Not only is identification of new species incomplete, many species have been over counted because two or more names have been applied to each of them. There is no common database to refer to for all species and the currency of references used for specific taxonomic groups (often classes) varies significantly.

Most species scores drop when family number is counted globally, but the differences vary significantly among families. In the Everglades, where West Indian manatee and West Indian mahogany are the only American species in their family, the global estimate of the West Indian manatee family number is 3 while the West Indian mahogany estimate is 575. A global metric would much more greatly reduce the influence of mahogany than the influence of manatees. The influence of American crocodiles and mangrove rivulus, the only American members of their family, would be reduced an intermediate amount and nearly equally. Using the estimated global numbers indicated here would reduce the score for these four Everglades species from 40.0 to about 5.6. The Kissimmee River score would drop from 18.7 to about 2.0 if the two species with less than 10 American species in the family were counted globally.

Other species with many more American members also have substantially more global members. The common wetland family Cyperaceae (the sedge family) globally has well over five times the American number of species, for example. The Unionidae (freshwater mussels), on the other hand, are particularly diverse in the United States and the scores of species in that family would most likely decrease only by about half—based on one global estimate of about 600 species in the family. The BSI scores of the Ohio River and Scioto T-dike projects, where numerous mussels occur, may rise much closer to the top ranks held by Florida sites, or even exceed them, if the family number was global instead of national. The potential effects of using the number of American species in the family appear to be most serious in south Florida. No other location in the United States is nearly as

affected by the difference between global and American measures of distinctiveness.

Ultimately, the best indicator of distinctiveness will rely on molecular techniques. Until that time, indicators based on taxonomic differentiation is a crude proxy, but one that seems necessary to capture the genetic level of diversity that determines species differences, the unique roles of species in sustaining ecosystems, and future options for resource use.

Weights for BSI Terms

The security status provides a qualitative basis for resource scarcity determination, but the weights used for each status level are the quantitative indicator of relative scarcity that improves the ability of the BSI to identify differences among projects. The idea that species are composed of distinct populations and that the long-term number and viability of those populations is a good indication of the security of species and their supporting ecosystems has been useful in species conservation planning (Stein 2008). The weights used here are based on the logic behind creation of the different levels of conservation status (Stein 2008, Faber-Langendoen et al. 2009).

For many species, the number and distribution of different population "occurrences" is an indicator of species security from extinction. From numerous observations of species status, a model that appears to define the relative security of many species between G1 and G4 ranks is a 4x progression between a maximum of 6, 24, 96, and 384 population occurrences for G1, G2, G3, and G4 species, respectively, when the populations are distinct, viable, and well dispersed in the original range. Based on that logic, increasing G1, G2, and G3 species to G5 status requires 64, 16, and 4 times the population number, respectively.

Large and mobile species that naturally exist in low densities often form few distinct populations over a relatively large range. Despite the low number of populations, they are not necessarily ranked as vulnerable to highly imperiled because the members are widely dispersed. Such ranks may be assigned when there is evidence that the numbers of individuals in the populations have been substantially reduced or are highly threatened, more or less in proportion to the fraction of population occurrences that generally determine the security status of most species. Therefore, the 4x progression model works reasonably well for them.

Other exceptional species are limited to one, two or a few populations in small habitats, including species restricted to freshwater spring, cave, and other isolated habitats. The numerical ceiling for these species is set by the limits of the small habitat and minimization of human impact. Numerous fish, amphipod, crayfish and other freshwater spring and cave species fall into this category. Many of these species may not have declined in population number, but are ranked as imperiled because all of the population members are exposed to some potentially lethal threat. Lethal changes in groundwater elevation and quality are the main sources of threat. The role of the Corps in improving the lot of these species is limited because the sources of threat are largely outside its restoration authority. An exception is the Everglades, where three vulnerable to highly imperiled cave species are probably sustained by hydrology more like the past. Instead of population numbers, in these cases, the proportion of the entire species number is used to gauge the security status.

The weighting model for biodiversity security is a crude but scientifically derived way to indicate the relative scarcity of each status level consistent with the amount of knowledge that exists. The precise numbers, locations, and viabilities of all population occurrences are rarely known in their entirety, requiring some approximation. Both underestimates and overestimates are possible. However, the approach is amenable to improvement through further research. Ultimately, molecular indications of distinctiveness should greatly improve the measurement of heritage value added for each species restored in supportive ecosystems.

The default weight used for the distinctiveness term is 1.0. It places more emphasis on the sustainability of unique attributes than the species themselves because the range is from 1 to about 2000, while the range for species security status is from 1 to 64 for G1 to G4 species. This is based on the assumption that each species must differ from all other species by at least one unique attribute that probably influences its function in the ecosystem and that functional uniqueness in the ecosystem is more important in sustaining the diversity of ecosystem attributes than sustaining all species. For example, there are many species of freshwater mussels in each of a few genera that seem to perform quite similar functions in stream systems. The loss in ecosystem diversity would be very small compared to the functional loss of the quite unique hellbender from those same systems. The probability that a unique enzyme will eventually

prove to be of economic benefit is more likely in the hellbender than among the mussels, which share enzymes largely in common.

The relative emphasis of the weights can be changed by policy if science or other good reasoning indicates a need to increase or decrease the relative contribution of individual species attributes to the BSI score. One way to make the weights more equal would be to increase the weights of the species security status by about 30 times each. Then a G1 weight would be 1920 (near the maximum of 2000 species in a family), G2 would be 480, and G3 would be 120.

Taxonomic Information

This source of potential error is one of the least problematic. In general, taxonomic information for the groups that are considered by the BSI is well established. A vertebrate or vascular plant species is occasionally determined to be more or less closely related to another species than previously thought. Such determinations are more common for certain invertebrates, such as gastropods (snails), but the taxonomy is improving rapidly.

The RSI approach to resource scarcity and value

The state of knowledge for the ecosystem-based approach to scarcity used in the RSI calibration is less standardized than the BSI approach. The ecosystem approach is the main way that the relative scarcity of ecological resources is indicated. It includes the scarcity of the ecosystem based on evidence (not standardized) as well as the scarcity of connectivity for species (not identified). The presence or absence of ESA protected species plays a much smaller role.

Since all species live in physical habitats and ecosystems, and all ecosystems and physical habitats house species of some kind, the Corps could theoretically use species, physical habitat, or ecosystems to approach the problem of ranking projects based on their scarcity. Whichever approach is taken, it should be universally applied to avoid the subjectivity and doubt introduced by comparing the results of different approaches. It should also be recognized that measures of habitat and ecosystem scarcity are indirect indicators of species scarcity. The RSI mixes approaches making comparisons difficult. The BSI is standardized and comparisons are clear.

An ecosystem-based approach has one clear advantage over a species-based approach. Once ecosystem boundaries and changes have been identified, relative scarcity is conceptually easy to determine based on the geographical fraction of the ecosystem lost to human impact. In many parts of the world, biodiversity conservancies use this approach to estimate the relative scarcity of terrestrial and vegetated wetland ecosystem types based on the structural characteristics of dominant vegetation in lieu of more precise species information (Groves 2003, Cole 2014a). Remote sensory information has greatly increased the feasibility of this approach.

In practice, ecosystem-based approaches encounter a number of difficult problems. Ecosystems are typically identified by gross structural attributes (e.g., vegetation height and form, channel form), which are often poor indicators of diversity. Based on the data presented here and in Master et al. (2000), the large differences in imperiled species diversity within northern and southern ecosystems in the United States are not reflected in the percentages of ecosystems that have been converted to other ecosystem conditions. In addition, many forms of ecosystem change do not totally destroy the native diversity, leaving some of it intact. Thus the loss of national biodiversity may be overestimated by methods based on crude measures of geographical area altered. Species are not always evenly distributed throughout ecosystems either and the lost fraction of the ecosystem may overestimate or underestimate the species loss. Discerning ecosystem boundaries within terrestrial and aquatic environments typically works better for terrestrial ecosystems than for aquatic systems, where the defining features are often obscured (bottom structure) or totally invisible (water quality).

An essential question must be asked when drawing ecosystem boundaries: How different should they be from other ecosystems? Distinctiveness is therefore as much a concern for ecosystems as it is for species-based indicators of scarcity. Ecosystem scarcity depends on ecosystem distinctiveness. Ecosystems that are very different from other ecosystems are more valuable to sustain than ecosystems that differ by a very small amount from other ecosystems because the different ones support a greater number of unique species and contribute more to biodiversity. One of the numerous problems with the RSI is that ecosystem distinctiveness is not clearly considered.

Placing boundaries on ecosystems is challenging. Ecosystems often change gradually through transition zones that defy neat boundary identification. Many different ecoregion and ecosystem typologies have been developed as a consequence. The history of demarcating wetland boundaries for enforcement of the Clean Water Act has shown the problems encountered in differentiating wetland habitats (NRC 2001). Ecologists are increasingly recognizing that most ecosystems are novel ecosystems that have changed significantly and are continuing to change as climate and other human effects accumulate (Hobbs et al 2013). The extent to which this is a valid assessment calls into question the validity of any judgment about scarcity based on out-dated assumptions about ecosystem integrity.

Then there is a matter of scale. Theoretically, ecosystems of global scale can be subdivided to very fine levels of difference, but no concept of division that is equivalent to the species concept in taxonomic division exists to theoretically anchor ecosystem divisions. The species concept has evolutionary meaning that cannot be duplicated in habitat and ecosystem typologies. Determining the proper scale of division is arbitrary; yet, scale makes a big difference in determining scarcity. Large divisions of ecosystems and habitats can be quite common even though finer divisions within them may appear to be quite scarce.

Physical features of ecosystems can naturally change dramatically without much impact on species diversity. In river channel and coastline environments distinctive geophysical features often disappear altogether locally until the next major geophysical event restores. For example, flood control has caused erosion-dependent floodplain habitats to disappear, but they soon reappear when the control structures are removed. Water, sediment, stone, nutrients, gasses and other physical materials may be distributed in ways that make them scarce resources for species requirements, but they are not independently scarce. Unless populations of unsustainable species are threatened by their loss, restoration of geologically ephemeral features is of questionable nonuse value, because the geophysical materials composing the features are typically abundant and can be reassembled as needed. Extinct species cannot be reassembled as needed. Restoration can always rearrange the geophysical aspects of ecosystem later, if necessary, when truly scarce ecosystem components justify the need.

In contrast to species, there is no evidence that ecosystems go permanently extinct independent of the species that use and compose them. Ecosystem extinction occurs species by species. Because species extinction is accelerating, much research in the field of conservation biology has addressed population viability requirements in numbers of individuals required to sustain population characteristics (e.g., Primack 2014). Little of that kind of research exists for ecosystems.

From the standpoint of practicality, the absence of any widely accepted database for ecosystem security and distinctiveness is a real impediment to developing a useful metric. A growing number of habitat and ecosystem characterizations have been published, but none provide the necessary data. There is no general consensus about characterization and boundaries. The NatureServe Explorer database provides that general consensus based on species.

Using The 8-Digit HUC To Identify Species

One of the more difficult aspects of scoring is determining which G1-3 species found in the 8-digit HUC should be excluded. It requires ecological perspective that is not necessary in other aspects of BSI use. The decision is easy when the species inhabit entirely different environments from those addressed by the project. When in doubt, the general rule is to err in favor of the possibility of species response to restoration actions. One example is the Asian carp problem in the Great Lakes. Planktivorous fish in the Great Lakes are clearly threatened by invasion of potential competitors, but the effect they may have on piping plovers is less clear because their food source is in shallow water along beaches rather than offshore waters where the Asian carp are more likely to occur. But the plover was included because the food source is within potential reach of the Asian Carp and could be affected. On the other hand, species found in tributary streams were excluded because of entirely different food habits and marginal habitat conditions for Asian carp.

Separation of floodplain and upland species is also challenging. Generally speaking, if the project or program is not explicit about restoring natural flood scour in the floodplain, species that respond to scour are not included. Similarly, the mesic requirements of some species have to be complemented by some period of soil flooding or saturation. Species that respond to management associated with terrestrial settings, such as grazing management, ordinarily would be excluded unless hydraulic

considerations, such as periodic floodplain flooding, also are required. Facultative species that are widely distributed along a soil moisture gradient typically do not require wet soil conditions to recover and generally would not be included without a strong case being made for other considerations (such as no other suitable alternatives anywhere in the region).

Ordinarily, terrestrial restoration does not require hydrologic alterations and typically responds to management of land use (agriculture, grazing, urban use) and fire. Any species that does not require some form of hydrologic improvement to recover in the project area usually should be excluded from the list. They may respond in a project area as a consequence of incidental changes in land use or fire frequency, but they are typically not targeted in Corps ecosystem restoration projects. Fox Island, in the Mississippi River is a case in point. The restoration emphasis is to improve the hydrology of the island for the desired water-dependent ecosystems. Prairies are mentioned among the ecosystems, but fully terrestrial prairie species would not qualify because they do not depend on hydrologic or hydraulic changes. The beaches of barrier islands (e.g., Barataria) are continuously reshaped by hydrologic events and all species that depend solely on beach and dune habitat would be included. Some terrestrial species may inhabit barrier islands incidentally, but do not require them to do well. They may however, become established incidentally or as a consequence of management by a cooperator, but that should not count to the value added by the Corps.

There must be a reasonably significant connection of the project site to the species. Generally speaking, if a species is not recorded from the watershed, it is discounted. There may be justifiable reasons to include a species when it has not been recorded. The main case in point in this study was the decision to include two adjacent HUCs for Scioto T-dike because it is located very near to the shared boundaries of the two. Vague connections to highly mobile species have been claimed in the past, such as for Bald Eagles. But if there is no scientifically established observation in the HUC they are not included. In the study, for example, the whooping crane was mentioned as flying through the Snake River project, as it does through much other habitat, but the connection to the specific project are too tenuous to link any to any measurable impact on the crane. No traditional migratory habitats are known to be used by the crane (Howe 1989).

This aspect of BSI application is most vulnerable to index inflation. The decision to include or exclude a species should be carefully documented based on the available information, including the professional judgment of personnel from local natural heritage programs and academic institutions. Professional review at the national level is another safeguard for assuming commonality in practice. But, whenever, there is significant doubt, the rule is to err on the side of including the species in question.

There is justifiable concern that the documentation of species occurrences among HUCs is uneven—that with greater sampling effort species would have been observed that were overlooked. Consultation with locally knowledgeable professionals is always advisable. A project may suffer in rank simply because long-past surveys were unevenly conducted and scarce species were overlooked. This source of error is more likely for rare species with spotty distributions than with abundant, widely dispersed species. One way to address the issue is to combine HUCS. But that runs the risk of including species that were never anywhere near the potential project area. Either way, some error must be accepted as a necessary effect of incomplete knowledge. In some instances, a case might be made for including a species not recorded in the HUC if natural heritage or equivalent authorities can make a strong case for its past occurrence in the HUC.

Accuracy of Project Reports

This study depended on a brief, program level summary of project reports about the anticipated nature of the project. In actual application, the full detail of those reports is essential for careful vetting of the species that are likely to be significantly affected by the project through hydrologic and related geomorphic modifications. Minimally, reports need to indicate the type and specific locations of the habitats to be modified. Embellishment is a concern in this regard. The main means of control is requirement of as detailed documentation of claims as can reasonably be expected at this stage of the planning process.

Accuracy of Ecological and Management Data

Ecological and management data are most relevant for feasibility study ranking during the evaluation of G1-3 species inclusion or exclusion. The accuracy of ecological and management data maintained by NatureServe Explorer is determined by the information available and its interpretation into database digests. The information is scientifically referenced and

original sources can be consulted. In actual practice, local natural heritage professionals should be consulted to gain insight into unpublished knowledge and professional judgment.

Implications for Project Construction

The BSI for project construction ranking differs primarily because it has a risk term and viable population changes are quantified explicitly. Guidance for risk term calibration is under development. But two important project construction ranking implications are evident. First, a significant reduction of the BSI can occur when numerous species have been included based on uncertain knowledge that is resolved during risk term calibration. Second, projects with a large number of small G1-3 species are more likely to hold their BSI score value for construction than projects dominated by a few large species.

A project with a high score for feasibility study has some advantage over other projects going into the calculation of the BSI used to rank projects for construction. The project construction score will typically be lower for most sites because the risk term varies between 0.1 and 0.9 (only rarely would a risk term be 0), and only a fraction of a fully viable population will be restored for some species. However, the score can increase when a plan restores more than one viable population for several species. Because the lowest risk-term score is typically 0.1, no projects will receive a 0 score for construction unless it is determined that it does not involve habitat improvement or that the form of improvement will have absolutely no positive effect or negative effect.

For two reasons, a number of large species that contribute largely to the BSI score at the case study sites are not likely to contribute more than a fraction of the feasibility study score to the project construction score. In many cases, a significant fraction of a viable population already exists in the habitat. For example, Florida populations of American crocodiles, West Indian Manatees, and West Indian mahogany would contribute only a fraction of a viable population unit to the score because they are already well established. This is also true for a number of sites now occupied by sturgeon and may be true for hellbenders and alligator snapping turtles.

The natural density of species, while ignored for ranking feasibility studies for annual budget allocation, is an important variable in ranking projects for construction investment. Many projects are likely to be limited to a size

far smaller than needed to support a viable population of a large species. Many smaller species may also be partially established in study sites leading to some diminishment of their potential score, but many other small species do not now exist in the habitat at a project site and would receive full value for recovery of a viable population at the site. In addition, two or more discrete populations may be restored for smaller species. Thus the form of the BSI used to rank projects for construction investment will tend to reduce the advantage of sites ranked high for feasibility study because of the scarcity and distinctiveness of large species. Once again, the Everglades project, where several viable populations of mangrove rivulus may be recovered, is a good example.

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Appendix A: Guidance for Use of NatureServe Explorer

Entering the Database

Go the NatureServe Explorer Web Site at http://explorer.natureserve.org/. Select "Search" from choices at the top of the page. Search by Taxonomic Group. Make sure that the box that includes subspecies in the search is **not** checked. Only species are to be included. Within groups, you must include all vascular plants, vertebrates, mollusks, and crayfish.

Selecting Species Name, Status and Location

Two approaches may be used. One approach requires that some groups be ignored in the lists that are provided. Another approach preselects for the appropriate groups. The simplest approach only requires that a box indicating whether or not to include subspecies and populations is deselected and that all species are searched for. If it is not "unchecked" subspecific groups will be improperly included if the planner is not careful to delete them later. Then, just below the list of choices in blue, select "Status". Include only those groups that by policy have been given a positive score. This will most likely include G1, G2, and G3 as done in the case study but may include some alternative selections. It will most likely not include GX and GH, or G5 because these are already extinct (no way to restore them based on existing information) or are already completely secure from extinction.

Next, select "Location" from the blue choices. National, State, watershed (HUC), and county choices are provided. The watershed approach has been adopted by the Corps and is the location method advised here. A useful tool for this purpose identifies the boundaries of watershed HUC to the eighth place. It can be found on the USGS website under "Science in your watershed" (http://water.usgs.gov/wsc/map_index.html). Depending on the size of the project, more than one HUC is appropriate to accommodate the full size of the project area. NatureServe Exploer provides an easy criteria check to make sure the criteria are properly chosen before conducting the search.

A bit more complicated approach requires selection of specific groups for the search. Select “informal names” and then check Vascular Plants Vertebrate Animals. This will produce a list of species in those broad categories. Once that is done, the status and location is selected using the previously described approach do the search and store the list that is produced. Next, select the down arrow for invertebrate animals. Check the box for Mollusca. Then check to make sure your status and location criteria remain the same, search for the mollusk list and store. Go back to invertebrate animals and select the down arrow for “Crustacea”. Then select crayfish, isopods, amphipods, and freshwater, fairy, clam and tadpole shrimp, but leave out “other Crustacea”. Check the criteria again, including the watershed data. Then Select “Search Now”.

Once a list is produced for a particular group the data for each species can be called up directly. You are provided information on Taxonomy, Conservation Status ((Security Status), distribution, ecology, economic attributes, management information, population/occurrence, delineation, population/occurrence viability, authors, references, and use guidelines. Particularly relevant to you at this point is information on species distributions, to confirm they are in your general area, and ecological information. In addition, you should check to make sure the species is native (usually this is not a problem for G1-G3 species). Under ecology and life history is information that will help you to decide whether to include the species or not. If your restoration is for aquatic species only, for example, all terrestrial species would be left out. If your project is for floodplain/riparian species, all upland and fully aquatic species would be excluded.

You may notice that some species which use the project area habitat incidentally are not included in the list. For example, a river restoration project may serve incidentally as habitat for large predatory birds, but, unless the habitat in that watershed is especially relevant, they will not show up in the list (Bald Eagles may be seen incidentally almost anywhere along rivers in the U.S.) This only means that the restoration of the habitat is not likely to have any measurable effect on those species.

This should provide you with a complete set of the indicator species of the security status in the region of the project area.

Identifying Number of Species in Taxonomic Family

Information on the number of species in a Family is easily retrieved from NatureServe Explorer as well. For this exercise for each species you should note the major taxonomic chain provided which includes Kingdom, Phylum, Class, Order, and Family. You will need this information. Go to the taxonomic groups and in this case select “scientific names”. Before selection, make sure that all subspecies are excluded by assuring that the box is not checked. Select the down arrow. Identify the correct Kingdom, then, in sequence, the correct Phylum, Class, Order, and Family. Check the Family but do not select now yet. First select the “Status”. Be sure that all categories are checked except of GX (GH are included here because they may still be extant). Then select “location”. Select all states of the United States. Make sure that just above that table that you identify native species only for inclusion in the list. Then select “Select Now”. At the top of the list will be identified the total number of species in the family. This information is used to calculate the distinctiveness term in the BSI.

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14. ABSTRACT

The Biodiversity Security Index (BSI) was applied to 23 project sites ranked for restoration feasibility study annual funding by the U. S. Army Corps of Engineers. The sites were selected to represent a wide range of geographic, ecological, and engineering attributes. The BSI application method described here relies largely on data presented in the NatureServe Explorer database. Data used to calculate the BSI is summarized for each site. BSI score variation among the 23 sites is influenced by three variables: the total number of species that are moderately to highly vulnerable to extinction (G1-3) as indicated in NatureServe Explorer, the scarcity weights placed on G1-3 levels of vulnerability (greatly imperiled, imperiled, vulnerable), and species distinctiveness as indicated by the number of American species in the taxonomic family. BSI scores are compared to the scores of an existing resource significance index (RSI) used to rank the projects for annual Federal budget allocation. The correlation of log-transformed BSI and RSI scores explains half of the variation ($R^2 = 0.50$). Habitat size and resource scarcity appears to explain much of the correlation. The RSI does not discriminate among the projects as well as the BSI. Score differences probably result from the emphasis placed on habitat scarcity by the RSI and species scarcity by the BSI. Possible issues pertaining to BSI use for feasibility study ranking are discussed and compared with the RSI.

15. SUBJECT TERMS

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