gap

KEEPING COMMON SPECIES COMMON

# Gap Analysis

BULLETIN

No. 15

A Geographic Approach to Planning for Biological Diversity

U.S. Department of the Interior
U.S. Geological Survey

2007

USGS
science for a changing world

## Contents



continued on back cover

# The Gap Analysis Program ... in Brief

The Mission of the Gap Analysis Program (GAP) <http://gapanalysis.nbii.gov> is to promote conservation by providing broad geographic information on biological diversity to resource managers, planners, and policy makers who can use the information to make informed decisions.

As part of the National Biological Information Infrastructure (NBII) <http://www.nbii.gov>—a collaborative program to provide increased access to data and information on the nation's biological resources--GAP data and analytical tools have been used in hundreds of applications: from basic research to comprehensive state wildlife plans; from educational projects in schools to ecoregional assessments of biodiversity.

The challenge: keeping common species common means protecting them BEFORE they become threatened. To do this on a state or regional basis requires key information such as land cover descriptions, predicted distribution maps for native animals, and an assessment of the level of protection currently given to those plants and animals.

GAP works cooperatively with Federal, state, and local natural resource professionals and academics to provide this kind of information. GAP activities focus on the creation of state and regional databases and maps that depict patterns of land management, land cover, and biodiversity. These data can be used to identify "gaps" in conservation--instances where an animal or plant community is not adequately represented on the existing network of conservation lands.

GAP is administered through the U.S. Geological Survey. Through building partnerships among disparate groups, GAP hopes to foster the kind of collaboration that is needed to address conservation issues on a broad scale.

For more information, contact:

John Mosesso
National GAP Director
703-648-4079

Kevin Gergely
National GAP Operations Manager
208-885-3565

# FEATURES

# Assigning Conservation Management Status to Alaska's Lands

Corinne Smith[1], Shane Feirer[2], Randy Hagenstein[2], Amalie Couvillion[2], Sarah Leonard[2]

## Introduction

In 2005, Alaska celebrated the 25th anniversary of the Alaska National Interest Lands Conservation Act (ANILCA), which protected over 100 million acres of Federal land in Alaska for conservation purposes. The Act doubled the total acreage in the U.S. national park system and created or expanded national wildlife refuges and national forests across Alaska. The Act arguably made Alaska one of the most protected places in the United States. Its network of protected areas includes 15 national parks, 2 national forests, 16 national wildlife refuges, and more than 4.7 million acres (5.9 million hectares) of state-owned lands managed for conservation.

Because 90 percent of Alaska is owned by the State and Federal governments, one might assume that conservation in Alaska mostly is about how these lands are managed as opposed to the need for protecting new lands through acquisition, legislation, or private preserves. However, several studies elsewhere have shown that protected areas are often the least productive and least desirable lands (Nilsson and Gotmark 1992; Scott et al. 2001), and that huge gaps in biodiversity protection can exist in the face of what might seem to be a sufficient network of protected areas (Caicco et al. 1995; Rodrigues et al. 2004). We examined the distribution of land management and ownership across Alaska and used ecoregions as the unit for an initial assessment of how well the protected areas capture and protect the terrestrial biodiversity of Alaska.

In the United States, much emphasis has been placed on Federal public lands for their role in conserving national biodiversity (Crumpacker et al. 1988; Grumbine 1990; Brussard et al. 1992). Gap analysis assesses current levels of protection and identifies ecosystems and species that are underrepresented in protected areas (GAP 1998; Jennings 2000). The U.S. Geological Survey's (USGS) Gap Analysis Program (GAP) provides a framework for assigning conservation management status to different land management types (Scott et al. 1993; Crist 1994; Jennings 2000). Conservation management status (CMS) describes the degree to which land, particularly public land, is legally designated and explicitly managed for biodiversity conservation.

A complete gap analysis has not yet been conducted for Alaska. More than a decade ago, Schoen and West (1994) called for a gap analysis of Alaska to help agencies set conservation strategies across the state. Duffy et al. (1999) began that analysis by using the GAP framework to assess the degree of protection of Alaska's terrestrial biodiversity at a statewide scale. A gap analysis of Alaska is an important first step in determining an efficient approach to conservation in the state (Groves 2003).

## Assigning Conservation Management Status

Most of Alaska (Figure 1) remains in Federal ownership (67 percent), with the State owning 23 percent, and local governments and private entities owning 10 percent. Less than 1 percent of the landscape has been altered by agricultural, industrial, or urban development (Schoen and West 1994), so large-scale ecological processes continue with little human interference. For example, more than 6 million acres of taiga burned in the summer of 2004 (National Interagency Fire Center 2004), and caribou migrate hundreds of miles annually (Paulson and Beletsky 2001).

The GAP framework assigns land management types to four Conservation Management Status (CMS) categories according to the degree to which the land is explicitly managed for conservation (GAP 1998; Jennings 2000).

[1] The Nature Conservancy, Anchorage, Alaska.

[2] University of California Davis, Hopland, California.

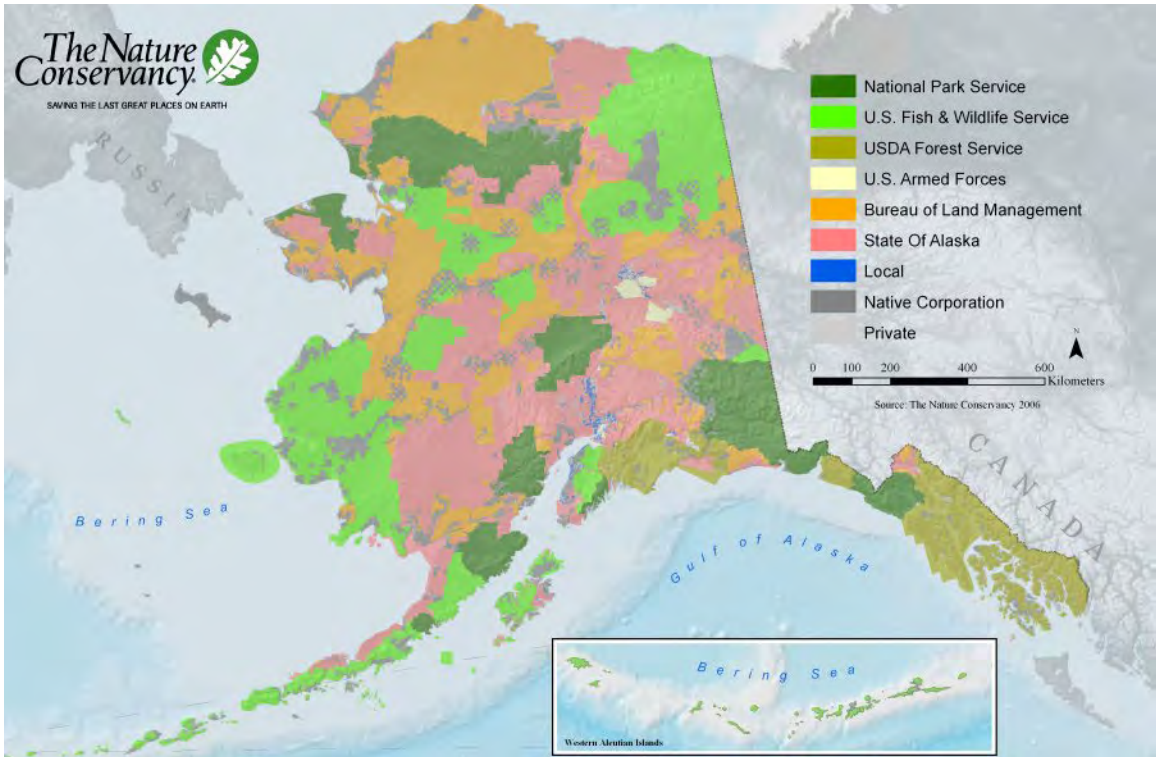



**Figure 1.** Land ownership in Alaska.

Criteria for CMS categories include size of area, what is protected, and overall management intent. In general, CMS 1 and 2 have a strong emphasis on conservation protections and have legal designations that are challenging to change. CMS 3 and 4 have no mandated conservation management or are used primarily for human activity. CMS 1 and 2 are assumed to provide high and medium protection, respectively, of species and landscape. In the lower 48 states, national parks, wilderness areas, and national wildlife refuges are typically classified as CMS 1 or 2.

The Nature Conservancy in Alaska and other conservation practitioners (Duffy et al. 1999) have found that the GAP CMS categories cannot be applied directly to management of Alaska lands in the same way as in the lower 48 states for several reasons. First, ANILCA allows uses of Federal protected areas that are typically banned in the rest of the country. For example in Alaska (but nowhere else), motorized vehicles are permitted in wilderness areas for traditional activities, such as subsistence hunting and gathering; thus we needed to determine whether these wilderness areas should be assigned a CMS 1 as in the lower 48. Second, the management of state protected areas (for example, forests, sanctuaries, preserves) varies from state to state. Third, national parks and preserves and wildlife refuges in Alaska tend to be managed more similarly to each other than the same units are in the lower 48 states and most have minimal levels of development. Therefore these Federal management types may be assigned different conservation management status than in the lower 48 in a gap analysis.

To determine how to assign CMS to Alaska lands, we reviewed the ANILCA legislation and state laws and regulations for state protected areas and interviewed Federal and state land managers to help us understand how those laws and regulations are applied to Alaska protected areas. We also reviewed GAP's criteria (GAP 1998) and developed a dichotomous key to assist us in assigning CMS (Table 1). We focused on the following factors to determine CMS for Alaska land management types:

- *Permanence of protection from conversion of natural land cover to unnatural cover*. We assumed that protected areas created through legislative action will be more difficult to dissolve than those created through administrative action (for example, National Monuments created by Executive Order) and thus offer longer-lasting protection.

**Table 1.** Dichotomous key with Conservation Management Status (CMS) definitions.

| | |
|---|---|
| A-1: | Can the management intent be determined through agency or institutional documentation? YES = Go to A-2. NO= Go to A-5. |
| A-2: | Is the land unit subject to laws or regulations that protect it from conversion of ALL or SELECTED features (e.g. state or federal legislation, deed restrictions, conservation easements). YES = Go to B-1. NO = Go to A-3. |
| A-3: | Is there a management plan that provides legally enforceable protection of SOME or ALL ecological features? YES = A-4. NO = A-5 |
| A-4: | **CMS 3.5** = A management plan or an institutional policy protects all or some ecological features, but protection is not considered permanent. |
| A-5: | Is the land publicly owned? YES = A-7. NO = A-6. |
| A-6: | **CMS 4.5** = Privately owned and either management intent is unknown or management intent doesn't protect for ecological features. |
| A-7 | **CMS 4.0** = Publicly owned, but not subject to a management plan or regulation that includes protection of ecological features. |
| B-1: | Is the total land system conserved for natural ecological function (no more than 5% of land is developed or intensely utilized)? YES = B-5. NO = B-2. |
| B-2: | Does management allow or mimic natural ecological disturbance events (e.g. fire, flooding) and allows only low anthropogenic use (e.g. renewable resource use or human visitation) on more than 5 % of land? YES = B-3. NO= B-4. |
| B-3: | **CMS 2.5 =** A management plan protects selected features and some or all natural disturbance events occur, but human use occurs on more than 5% of land. |
| B-4: | **CMS 3.0** = Management includes protection of select ecological features; intensive anthropogenic use (e.g. resource extraction, military exercises, developed/motorized recreation) occurs on more than 5% of the land. |
| B-5: | Was the unit created through executive or administrative actions with the management intent very similar to legislatively created units with Status 1 or 2 (e.g. Wilderness Study Area, National Monument, RNA)? YES = Go to B-5b; NO Go to B-5c |
| B-5b: | **CMS 2.2** = A management plan or an institutional policy protects all ecological features, but protection is not considered permanent. |
| B-5c: | Does management allow or mimic natural ecological disturbance events? YES = B-7. NO = B-6. |
| B-6: | **CMS 2 =** A management plan protects the total land system but some/all natural disturbance events are suppressed and human use occurs on more than 5% of land. |
| B-7: | Is motorized access prohibited? Yes = B-8. NO = B-9. |
| B-8: | **CMS 1.0 =** A management plan permanently protects the total land system, allowing natural disturbance events; motorized access is limited. |
| B-9: | **CMS 1.5 =** A management plan permanently protects the total land system, allowing natural disturbance events; motorized access is generally allowed. |

- *Relative amount of land maintained in a natural state.* We looked not only at how much of the protected area has been developed, but also how much of the unit is intensely used for human activities such as recreation or timber harvest. Most protected areas in Alaska have limited development and most federal units are very large. Thus, we used the 5 percent limit suggested by GAP (1998) as a threshold for development and intense human utilization.
- *Ecosystem management versus single species or feature management.* We assumed that lands managed for all species will protect overall biodiversity better than those managed for particular elements of biodiversity.
- *Management of natural disturbances.* Management that allows natural processes such as fire to occur with no or minimal interference received a higher CMS than lands where natural processes are suppressed.

- *Motorized access.* Most public lands in Alaska are open to some types of motorized access. We gave the most protective CMS 1 to lands where motorized access is very restricted or prohibited.

To distinguish significant differences within the four GAP conservation status categories, we defined intermediate conservation status categories for Alaska (Tables 1 and 2).

**Table 2.** Conservation Management Status assignments to Alaska land management.

| CMS | AGENCY | DESIGNATION |
|---|---|---|
| 1 | National Park Service | National Park, Wilderness Area |
| | U.S. Fish and Wildlife Service | Wilderness Area |
| | U.S. Department of Agriculture, Forest Service | Wilderness, Wilderness Monument, Wilderness Monument Research Natural Area, Wilderness Monument Special Area, Wilderness Special Area |
| 1.5 | National Park Service | National Preserve |
| | U.S. Fish and Wildlife Service | National Wildlife Refuge |
| | U.S. Department of Agriculture, Forest Service | Wilderness Monument Wild River, Wilderness Wild River |
| 2 | Bureau of Land Management (BLM) | National Conservation Area |
| | State of Alaska | State Game Sanctuary, State Park, State Marine Park, State Wilderness Park, State Wildlife Sanctuary |
| | U.S. Department of Agriculture, Forest Service | Land Use Designation (LUD) II, Research Natural Area |
| | Bureau of Land Management | Area of Critical Environmental Concern |
| 2.2 | National Park Service | National Monument |
| | U.S. Fish and Wildlife Service | Research Natural Area |
| | U.S. Department of Agriculture, Forest Service | Back country Prescription, Municipal Watershed, National Monument, Old Growth Habitat, Primitive Prescription, Research Natural Area, Proposed RNA, Recommended Wilderness |
| | Bureau of Land Management | National Conservation Area, Wild & Scenic River, Wild River, Research Natural Area |
| 2.5 | State of Alaska | State Critical Habitat Area, State Game Refuge, State Preserve, State Range Area, State Special Use Area, State Wildlife Refuge |
| | U.S. Department of Agriculture, Forest Service | Brown Bear Core Area, Fish and Wildlife Conservation Area; Fish, Wildlife and Recreation Prescription; Forest Restoration, Remote Recreation, Scenic River, Semi-Remote Recreation, all Wild River designations, Recreation River |
| | National Park Service | National Historical Park |
| | Bureau of Land Management | National Recreation Area |
| 3 | Bureau of Land Management | National Petroleum Reserve |
| | State of Alaska | State Forest, State Multiple Use Area, State Public Use Area, State Recreation Area, State Recreation River, State Resource Management Area, State Restricted Area, State Special Management Area |
| | U.S. Armed Forces | Military Reservation |
| | U.S. Department of Agriculture, Forest Service | Experimental Forest, LUD III, LUD IV, Modified Landscape, National Forest, Scenic Viewshed, Timber Production |
| | Bureau of Land Management | Undesignated BLM lands |
| 4 | Local | Municipal |
| | State of Alaska | State Recreational Mining Area, State Undesignated Lands |
| | U.S. Department of Agriculture, Forest Service | Mining Claim with Approved Operations Plan, Transportation/Utility Corridor |
| 4.5 | Private | Native Allotment, Native Corporation, Private |

The most protected lands, CMS 1 and 1.5, are managed for the entire ecosystem and have minimal development. CMS 1 lands, national parks and wilderness areas, are distinguished from CMS 1.5 lands, national preserves and wildlife refuges, by restrictions on motorized access and sport hunting. All or selected natural features are protected by law or a management plan on the cumulative CMS 2 lands, but low intensity human use occurs on more than 5 percent of the land. These lands include State parks and refuges, parts of national forests not used for timber harvest, wild and scenic rivers, and Bureau of Land Management (BLM) conservation areas. CMS 3 lands may protect selected natural features or have minimal development, but the intent of the management is for intensive human activities like resource extraction or motorized recreation on more than 5 percent of the land. Recreation areas, military bases, and national forests fall into this category. We separated CMS 4 lands into public and private ownership. CMS 4 public lands are developed or the management intent primarily is for human use, such as mining. Determining the management intent for private lands, including Native corporations' holdings and Native allotments, was beyond the scope of this project, so we have conservatively assumed that all private lands are primarily managed for human use. For analysis in this paper, we have collapsed the Alaska CMS categories to the four GAP categories, 1–4.

## Developing a Conservation Management Status Spatial Dataset

Once we determined CMS for the different land management types in Alaska, we mapped land management types and conservation management status across the state. To develop a land management dataset for Alaska, we collected GIS datasets from the Alaska Department of Natural Resources (ADNR), BLM, National Park Service (NPS), Chugach National Forest, Tongass National Forest, and U.S. Fish and Wildlife Service (USFWS). The ADNR dataset identifies land ownership at the section level (640 acres) but does not differentiate among the various land designations managed by each agency. The boundaries of state and Federal protected areas were delineated with GIS datasets from each agency. The BLM maintains a GIS dataset of Alaska Native allotments, which range in size from 40 to 160 acres. In total, we joined 36 GIS datasets to develop a statewide land management dataset. Boundary precedence was assigned in the following priority: Native Allotments, NPS, USFWS, BLM, and ADNR. We then mapped the CMS of each land management type represented in the spatial dataset.

## Assessing Conservation Management Status Across the State and Ecoregions

We evaluated the distribution of CMS 1 and 2 lands across the state and ecoregions in Alaska. An ecoregion is a geographic area that shares common geology, soils, climate, and vegetation. While Duffy et al. (1999) used the 28 ecoregions described by Bailey et al. (1994), we used a more recent ecoregion map developed by Nowacki et al. (2001). Nowacki et al. (2001) delineated 32 ecoregions in Alaska; these ecoregions are either wholly in Alaska or extend from Alaska into western Canada or the Russian portion of the Bering Sea (Figure 2).

Revisions to how lands were classified as CMS 1 and 2 improved the picture of conservation at the statewide scale from the Duffy et al. (1999) study. Our inclusion of national wildlife refuges and some forest service lands in CMS 1 and 2 increased the amount of protected lands from less than 19 to 43.6 percent statewide. Of Alaska's 365 million acres, 36.7 percent come under CMS 1, 6.9 percent under CMS 2,

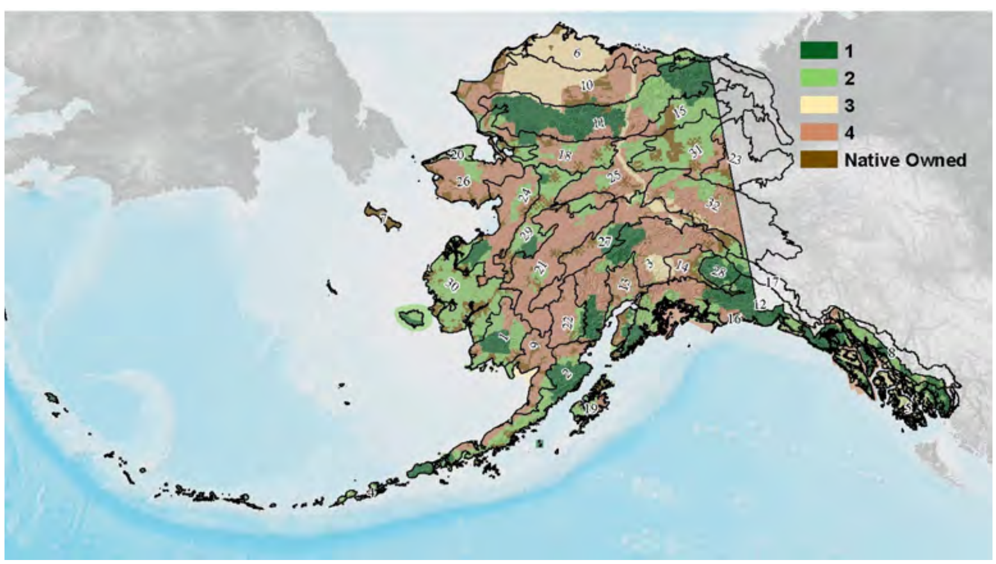



**Figure 2.** Conservation management status and ecoregions in Alaska. (Ecoregion numbers correspond to Table 3.)

9.2 percent under CMS 3, and 47.2 percent under CMS 4 public and private lands (Figure 2). We determined that despite the overwhelming majority ownership (90 percent) by Federal and state government, less than one-half of all public lands (43.6 percent) are managed for high or medium conservation (CMS 1 and 2).

At the ecoregion level, the amount of land in CMS 1 and 2 ranges from 6.9 percent in the Beaufort Coastal Plain to 100 percent in the Kluane Range (Figure 2; Table 3). Eleven of 32 ecoregions in the state have less than 30 percent of their lands in CMS 1 and 2. Collectively, these ecoregions comprise 40.6 percent of the area of the state, and thus a significant proportion of the environmental gradients represented by ecoregional differences are not captured in CMS 1 and 2 lands.

**Table 3.** Area and percentage of Conservation Management Status within Alaska's ecoregions .

| Ecoregion No. | Ecoregion name | Total area in Alaska (acre) | CMS 1 and 2 (percent) | CMS 3 (percent) | CMS 4 (percent) | Native-owned lands (percent) | CMS 1 and 2 and Native-owned lands (percent) | Increase with Native-owned lands (percent) |
|---|---|---|---|---|---|---|---|---|
| 1 | Ahklun Mountains | 9,565,730 | 68.1 | 0.3 | 23.6 | 8.0 | 76.1 | 11.8 |
| 2 | Alaska Peninsula | 15,745,320 | 70.7 | 0.1 | 18.1 | 11.2 | 81.8 | 15.8 |
| 3 | Alaska Range | 25,533,884 | 28.4 | 7.9 | 58.1 | 5.5 | 34.0 | 19.4 |
| 4 | Aleutian Islands | 3,302,471 | 80.7 | 0.0 | 0.0 | 19.3 | 100.0 | 23.9 |
| 5 | Alexander Archipelago | 13,022,755 | 53.4 | 19.4 | 22.9 | 4.3 | 57.8 | 8.1 |
| 6 | Beaufort Coastal Plain | 14,588,080 | 6.9 | 68.2 | 16.4 | 8.4 | 15.3 | 121.0 |
| 7 | Bering Sea Islands | 2,353,983 | 69.8 | 0.0 | 0.0 | 30.2 | 100.0 | 43.2 |
| 8 | Boundary Ranges | 5,001,553 | 78.5 | 9.0 | 11.8 | 0.6 | 79.1 | 0.7 |
| 9 | Bristol Bay Lowlands | 7,903,765 | 14.5 | 12.0 | 56.0 | 17.4 | 32.0 | 119.8 |
| 10 | Brooks Foothills | 28,473,856 | 8.1 | 42.9 | 35.8 | 13.2 | 21.3 | 163.5 |
| 11 | Brooks Range | 31,810,340 | 77.2 | 4.1 | 16.7 | 2.0 | 79.2 | 2.6 |
| 12 | Chugach-St. Elias Mountains | 19,559,239 | 71.5 | 0.8 | 25.0 | 2.8 | 74.2 | 3.9 |
| 13 | Cook Inlet Basin | 7,186,201 | 30.9 | 1.3 | 44.2 | 23.5 | 54.5 | 76.1 |
| 14 | Copper River Basin | 4,729,105 | 24.6 | 9.4 | 42.4 | 23.6 | 48.2 | 96.0 |
| 15 | Davidson Mountains | 7,166,881 | 72.1 | 0.0 | 9.4 | 18.5 | 90.6 | 25.6 |
| 16 | Gulf of Alaska Coast | 4,346,096 | 44.2 | 0.7 | 44.4 | 10.7 | 54.9 | 24.3 |
| 17 | Kluane Range | 1,242,278 | 100.0 | 0.0 | 0.0 | 0.0 | 100.0 | 0.0 |
| 18 | Kobuk Ridges and Valleys | 13,623,826 | 40.4 | 0.4 | 46.3 | 12.9 | 53.3 | 31.9 |
| 19 | Kodiak Island | 3,144,935 | 63.8 | 0.0 | 10.9 | 25.3 | 89.1 | 39.7 |
| 20 | Kotzebue Sound Lowlands | 3,462,872 | 69.5 | 0.0 | 10.1 | 20.4 | 89.9 | 29.3 |
| 21 | Kuskokwim Mountains | 21,092,243 | 10.4 | 0.0 | 83.4 | 6.2 | 16.6 | 59.3 |
| 22 | Lime Hills | 7,095,517 | 18.3 | 0.1 | 77.1 | 4.5 | 22.8 | 24.6 |
| 23 | North Ogilvie Mountains | 3,139,948 | 40.2 | 0.0 | 36.9 | 22.9 | 63.1 | 56.8 |
| 24 | Nulato Hills | 14,433,213 | 29.6 | 0.0 | 59.2 | 11.2 | 40.8 | 38.0 |
| 25 | Ray Mountains | 12,662,068 | 30.7 | 9.2 | 52.3 | 7.8 | 38.5 | 25.4 |
| 26 | Seward Peninsula | 11,699,290 | 13.7 | 0.0 | 70.2 | 16.1 | 29.8 | 117.6 |
| 27 | Tanana-Kuskokwim Lowlands | 15,818,173 | 20.3 | 9.5 | 55.1 | 15.1 | 35.4 | 74.6 |
| 28 | Wrangell Mountains | 3,537,087 | 96.0 | 0.0 | 0.0 | 4.0 | 100.0 | 4.2 |
| 29 | Yukon River Lowlands | 12,782,423 | 63.8 | 0.0 | 17.9 | 18.4 | 82.1 | 28.8 |
| 30 | Yukon-Kuskokwim Delta | 18,964,625 | 74.9 | 0.0 | 2.1 | 23.0 | 97.9 | 30.7 |
| 31 | Yukon-Old Crow Basin | 13,991,621 | 63.3 | 0.0 | 13.9 | 22.8 | 86.1 | 36.1 |
| 32 | Yukon-Tanana Uplands | 15,751,473 | 27.1 | 8.5 | 57.6 | 6.8 | 33.9 | 25.0 |

## Conclusions

Conservation of Alaska's terrestrial biodiversity is not as secure as one might guess from simply noting the total acreage under protection. If one considers the state as a whole, 43.6 percent resides in CMS 1 and 2 lands and Alaska may be viewed as an excellent conservation achievement. But Alaska today is an area of rapid climatic change and there is a need to provide options for resilience and future evolutionary response (ACIA 2004). In practical terms, this means that we should protect the ecological differences represented by ecoregions as much as possible. Lack of protection across the major environmental gradients of ecoregions increases the vulnerability of Alaska's plants and wildlife to the long-term effects of global warming.

[Note: The Nature Conservancy has also analyzed the distribution of conservation management status across the elevational gradient of Alaska and examined representation of vegetation classes by CMS and ecoregions. Contact Corinne Smith (corinne_smith@tnc.org) for more information about this work.]

## Acknowledgements

The conservation management status dataset was funded by the USGS Gap Analysis Program. Federal and state land managers from several agencies were indispensable for assigning conservation management status categories to Alaska lands. We thank Mary Gleason, Peter Kareiva, Stacey Solie, and Michael Jennings of The Nature Conservancy and Jocelyn Acryigg of GAP for reviewing this project.

## References Cited

(ACIA) Arctic Climate Impact Assessment. 2004. *Impacts of a warming Arctic: arctic climate impact assessment*. Cambridge University Press, Cambridge, United Kingdom.

Bailey, R.G., P.E. Avers, T. King, and W.H. McNab, editors. 1994. *Ecoregions and subregions of the United States*. U.S. Forest Service, Washington, D.C.

Brussard, P.F., D.D. Murphy, and R.F. Noss. 1992. Strategy and tactics for conserving biological diversity in the United States. *Conservation Biology* 6(2):157-159.

Caicco, S.L., J.M. Scott, B. Butterfield, and B. Csuti. 1995. A gap analysis of the management status of vegetation of Idaho (U.S.A.). *Conservation Biology* 9(3):498-511.

Crist, P.J. 1994. *Mapping and categorizing land stewardship: a handbook for conducting gap analysis*, Version 2.1.0, Gap Analysis Program. Available from http://gapanalysis.nbii.gov.

Crumpacker, D. W., S. W. Hodge, D. Friedle, and W.P. Gregg, Jr. 1988. A preliminary assessment of the status of major terrestrial and wetland ecosystems on federal and Indian lands in the United States. *Conservation Biology* 2(1):103-115.

DellaSala, D.A., N.L. Staus, J.R. Strittholt, A. Hackman, and A. Iacobelli. 2001. An updated protected areas database for the United States and Canada. *Natural Areas Journal* 21(2):124-135.

Duffy, D.C., K. Boggs, R.H. Hagenstein, R. Lipkin, and J.A. Michaelson. 1999. Landscape assessment of the degree of protection of Alaska's terrestrial biodiversity. *Conservation Biology* 13(6):1332-1343.

(GAP) Gap Analysis Program. 1998. *A handbook for conducting gap analysis*. U.S. Geological Survey, National Gap Analysis Program, Moscow, Idaho. Available from http://gapanalysis.nbii.gov.

Groves, C.R. 2003. *Drafting a conservation blueprint: a practitioner's guide to planning for biodiversity*. Island Press, Washington, D.C.

Grumbine, R.E. 1990. Viable populations, reserve size, and federal lands management: a critique. *Conservation Biology* 4(2):127-134.

Jennings, M.D. 2000. Gap analysis: concepts, methods, and recent results. *Landscape Ecology* 15:5-20.

National Interagency Fire Center. 2004. Wildland fire season summaries: highlights for the 2004 wildland fire season. Available from http://www.nifc.gov/fire_info/fire_summaries/summary_2004.htm

Nilsson, C., and F. Gotmark. 1992. Protected areas in Sweden: is natural variety adequately represented? *Conservation Biology* 6(2):232-242.

Nowacki, G.P., P. Spencer, T. Brock, M. Fleming, and T. Jorgenson. 2001. *Ecoregions of Alaska and neighboring territory (map)*. U.S. Geological Survey, Reston, Virginia.

Paulson, D., and L. Beletsky. 2001. *The ecotraveller's wildlife guide: Alaska*. Academic Press, London, United Kingdom.

Rodrigues, A., S.J. Andelman, M.I. Bakarr, L. Boitani, T.M. Brooks, R.M. Cowling, L.D.C. Fishpool, G.A.B. da Fonseca, K.J. Gaston, M. Hoffmann, J.S. Long, P.A. Marquet, J.D. Pilgrim, R.L. Pressey, J. Schipper, W. Sechrest, S.N. Stuart, L.G. Underhill, R.W. Waller, M.E.J. Watts, and X. Yan. 2004. Effectiveness of the global protected area network in representing species diversity. *Nature* 428:640-643.

Schoen, J.W., and E.W. West. 1994. Proactive strategies for conserving biological diversity: an unprecedented opportunity in Alaska. Pages 378-384 in *Transactions of the 59th North American Wildlife & Natural Resource Conference*. Wildlife Management Institute, Washington D.C.

Scott J.M., F. Davis, B. Csuti, R. Noss, B. Butterfield, C. Groves, H. Anderson, S. Caicco, F. D'Erchia, T. C. Edwards, Jr., J. Ulliman, and R.G. Wright. 1993. Gap analysis: a geographic approach to protection of biological diversity. *Wildlife Monographs* 123:1-41.

Scott, J.M., F.W. Davis, R.G. McGhie, R.G. Wright, C. Groves, and J. Estes. 2001. Nature reserves: do they capture the full range of America's biological diversity. *Ecological Applications* 11(4): 999-1007.

# Using GAP Data to Promote Land Trust Goals

Jill Maxwell[1] and Karen Dvornich[2]

## Introduction

A principal objective of the Gap Analysis Program (GAP) has been to provide information and data that can be used for proactive land management activities at the community and landscape level (Scott 2000). As of autumn 2006, 38 states have successfully completed GAP projects. In addition, the first regional GAP project, covering the five southwestern states of Arizona, New Mexico, Colorado, Utah, and Nevada has been completed, while two more regional projects are in progress in the Northwest and Southeast. Data from all these projects are available from the GAPServe data portal at http://gapanalysis.nbii.gov. The challenge now is implementation; that is, how to use these data to address those proactive land management activities that Scott (2000) envisioned. We will discuss how GAP data have been used successfully to promote conservation at a smaller scale and highlight some cases where Land Trusts have used GAP data to address planning and conservation issues.

GAP produces coarse scale spatial data, which are not always appropriate to apply to finer scale landscapes, such as municipalities, refuges, counties, or land trusts. GAP data generally do not contain enough detail for use in decision making at the land parcel scale for preparing habitat plans or plotting potential land trusts boundaries, for example. As a result, county- and city-level planners do not often use GAP data and maps for their decision-making (Gap Analysis Program, 2005). Nevertheless, some refuge, county, land trust, and city planners have used GAP data successfully.

In addition to predicted species range distribution, land cover, and stewardship data, GAP projects often include ancillary state- and region-specific datasets that can be useful for county and local scale planning. Even at 1:100,000 scale, GAP maps are educational tools that give landowners a perspective of their habitats in relation to neighboring parcels and landscapes. Some planners have used selective portions of these data, such as species lists and richness data or stewardship maps. GAP maps and data have been used in conjunction with other data. For example, Pierce County, Washington, planners updated older satellite imagery with new data for urban development, clear cuts, and roads, as well as with new data collected via groundtruthing (for example, field surveys). Finally, select counties have repeated the traditional GAP process at a smaller scale. Napa County, California, planners, along with the Napa Land Trust, conducted a hectare-scale gap analysis of their county. The resulting analysis identified local land parcels as conservation targets (Gap Analysis Program, 2005).

Several land trusts that have a conservation focus have found ways of working with GAP data to address and prioritize their conservation issues. Fostering conservation efforts on these privately held lands is crucial, as new development plans are converting more than 2 million acres of undeveloped land per year, according to the American Farmland Trust (2006). Simultaneously, 800,000 acres are protected annually by local and regional land trusts per year, either in new conservation easements or purchases. By 2003, l7 million acres were covered by 17,487 conservation easements held by local, regional, and national land trusts (High Country News, 2005).

GAP land cover data can be used by land trusts in numerous ways. A state or ecoregion-wide land cover map can be used to place a specific trust into a landscape context, enabling land trusts to make informed planning recommendations. The Eno River Association in North Carolina has been exploring the use of GAP data to provide information on land protection for common species and to identify development trends by looking at changes in impervious surfaces (Klugh Jordan, Director of Land Protection, written commun., 2007) Additionally, GAP data can help identify a prospective trust's connectivity to other protected lands. Using GAP land cover as a base map, land trusts can use finer scale open space maps, groundtruthing, and local experts to delineate fragments, riparian areas, or other small patches that might otherwise be missed. Species lists can be compiled to predict a species' occurrence on the land trust based on its habitat associations with the land cover data. A species' range on a land trust can be compared with that species' range in the surrounding state or region to assess the importance of conservation on that particular land trust.

[1] Gap Analysis Program, University of Idaho, Moscow.

[2] Washington Cooperative Fish and Wildlife Research Unit, University of Washington.

GAP data also can identify high priority lands based on critical habitats or species. The Inland Northwest Land Trust in northeastern Washington used maps of corridors identified by Washington GAP to decide which properties to buy in the future (Stevenson 1998). Similarly land trusts in southern and mid-Coast Maine use GAP maps of habitat data to prioritize and direct their land conservation efforts (Krohn 2002). The Palouse Land Trust (Moscow, Idaho) overlaid maps of available lands with existing GAP stewardship, habitat, and species range maps to prioritize lands with the potential to either provide large areas of natural habitat or to act as corridors (Svancara 2000).

## Pierce County, Washington

The Washington State Growth Management Act requires local jurisdictions to include open space in comprehensive plans and to adopt critical area regulations

Pierce County teamed with GAP personnel to develop a Biodiversity Management Network. Approximately 30 percent of the County falls within the Network that has been divided into 16 large blocks of land called Biodiversity Management Areas (BMA) connected by corridors. GAP predicted species lists, augmented by Natural Heritage locations and other data (such as fish and butterfly data) were instrumental in the identification of the BMAs. *NatureMapping* data were used to provide current data (post 1997 GAP data) for common species. *NatureMapping*, GAP's outreach program, involves citizens in the collection of data for scientists, and also trains them to design and carry out their own projects to complement the efforts of the collaborating local researchers, as noted below in the Bainbridge Island case study.

The Biodiversity Network coverage was integrated into the County's Comprehensive Plan's Open Space maps first in 1999. The land cover data were updated using 2000 satellite imagery and groundtruthed using aerial photos and driving routes. Only 1 percent of its core area was removed from the Network. The subsequent Biodiversity Network Assessment Report (McCalmon and Jacobson 2004) was used to amend the Comprehensive Plan. Pierce County currently is using the Biodiversity Network information in the community planning process (Dvornich et al. 2005). Community plans have used the Biodiversity Management Network to initiate new zoning that allows for lower densities and intensities of uses. Furthermore, *NatureMapping* data were used to overturn an appeal to downzone a BMA (K. Brooks, Pierce County, WA, written commun., 2006).

In an effort to validate the predicted species lists and involve the landowners within the BMAs, bioblitzes (a 24-hour inventory of plant and animal diversity in a designated area by experts and the public) recently have been conducted in two BMAs. Landowners received a comparison of the GAP species with species identified through the bioblitz for their use and (or) to help them with the process of applying for conservation easements. For example, GAP and bioblitz data were used by a land trust currently negotiating the purchase of 3,000 acres, of which almost one-half falls within a BMA. The GAP predicted species list is providing important information for all the land while the bioblitz data is helping the trust prioritize the sequence of land acquisition

The Washington Biodiversity Council selected the Pierce County efforts as one of their pilot projects to learn how: (1) coarse level analyses can be scaled down to community applications when combined with fine scale data, and (2) landowners within the BMA's respond to tax incentive programs.

## California Coastal Conservancy

In 2002, the Coastal Conservancy conducted a modified Gap Analysis to assist with regional conservation planning (Wild 2002).

The Conservancy had four goals for the analysis:

- Assess the degree of protection that existing open space provided to natural, terrestrial plant communities (natural communities) and the wildlife species they supported.
- Compare existing levels of protection to target levels.
- Establish priorities for conservation.
- Begin a discussion about what adequate protection would "look like."

The analysis was completed for land cover and stewardship and used the CA-GAP land cover map (Davis et. al. 1998) to depict location and extent of natural communities in the San Francisco Bay Area. They used a stewardship layer specific to the Bay Area (GreenInfo Network 2001). The extent of current protection was compared to two benchmark levels of protection. Natural communities already experiencing statewide declines were compared to a target level of 100 percent, while other communities were compared to a target of 20 percent. Communities were then prioritized according to endemicity, local development pressure, statewide rarity, and statewide protection level.

The Coastal Conservancy used the results of the analysis to educate the regional conservation community about natural communities in need of more protection, and to prioritize targets for future open-space areas.

## Bainbridge Island, Washington

Bainbridge Island Land Trust has helped local schools participate in *NatureMapping* since 1994 (NatureMapping, 2006). In 2006, the City of Bainbridge Island began working on a pilot Business and Biodiversity Offset Program to encourage biodiversity offsets during development (Washington Biodiversity Project 2006). GAP's habitat data were too coarse to help identify potential conservation targets because the habitat data identified less than 50 percent of habitats on the Island. So, as a first step, the Trust and city planners are using GAP species lists, which they compare to frequent sightings of 158 species reported by students all over the Island, to identify areas for land purchases, conservation easements, and further development. During the 2006–07 school year, each of 400 high school biology students will visit a "natural" area 6 times. The students will collect wildlife and plant data and generate a journal of photographs for each visit. Throughout the year, they will compile groundtruth data for a habitat map being developed concurrently with GAP habitat codes. This baseline map will be used to identify areas of high biodiversity, to monitor sites for species of interest, and for project development and (or) acquisition scenarios under consideration by the City and Trust.

## Sierra Foothill Conservancy, Central California

The Sierra Foothill Conservancy in California works with other partners under a CALFED Watershed grant managed by the State Water Resources Control Board. The Conservancy's core areas of field investigations include biodiversity and habitat. The *NatureMapping* Program provided a "Train the Trainers" workshop in early 2006 to 20 partnering organizations of the Sierra Nevada Alliance to train them how to collect biodiversity and habitat data. California GAP species and habitat type lists were provided to all participants for their use in field investigations. The McKenzie Table Mountain Preserve, as well as others maintained by the Conservancy, allows grazing and other uses on their property. Their goal is to identify the most diverse areas within each preserve, design management plans, and assess the plans through data collection and monitoring. A "Project Design" *NatureMapping* workshop in 2007 helped the Conservancy design monitoring projects with volunteers and schools to answer the different questions/plans for each preserve. These data will provide important information to the Conservancy, California's Natural Diversity Database, and for the California GAP update.

## Conclusions

While not all land trusts are established with the goal of habitat or wildlife conservation, GAP data can be useful for those that are. GAP provides data that land trusts can use to further their conservation efforts. Although data may have to be modified, or downscaled, they are a useful springboard to use for planning decisions. They can also serve as a tool for developing a management plan. As evidenced by Bainbridge Island, GAP modeling and classification protocols are tools that can be made to work at any scale. Landowners within the Pierce County Biodiversity Network understand they are developing stewardship plans for their BMA and "their" Network. Their conservation efforts may be local and at a fine scale, but will provide the cumulative effort needed to address long-term protection of biodiversity at a landscape (that is, coarse) scale.

In some cases, land trust, refuge, and city planners do not have sufficient training or knowledge of how to use GAP data. However, the lessons learned from Pierce County have shown this is not an insurmountable obstacle. The entire Pierce County biodiversity planning process has been documented and will be used to produce a set of guidelines for other planners. In addition, local community vision/stewardship plans now being finalized have been designed to be used as templates for other local jurisdictions.

Working with land trusts is important, because wildlife does not exist solely on publicly owned lands. If GAP wants to reach its goal of "keeping common species common," working with private landowners is invaluable. GAP also can benefit from these efforts because a closer relationship with private land holders, such as trusts, will facilitate the inclusion of more information into GAP databases as they are updated. For example, land trusts could contribute to GAP stewardship data by identifying the locations of conservation easements. Also, the creation of species lists by land trusts could help to verify species distributions and (or) expansions.

## References Cited


American Farmland Trust, Farmland Information Center. 2006, accessed December 33, 2006, at http://farmlandinfo.org/agricultural_statistics/

Dvornich, K.M., K. Brooks, M. Tirhi, J. Gardner. 2005. Development of a community stewardship program for the Pierce County biodiversity network. *Gap Analysis Bulletin* No. 13, p. 21-22.

Gap Analysis Program. 2006. *Gap analysis in Napa County, California*. Retrieved July 16, 2006 from http://gapanalysis.nbii.gov/applications

GreenInfo Network. 2001. *San Francisco Bay Area stewardship*, San Francisco, CA.

High Country News. 2005. Conservation Easement Statistics. Paonia, Colorado.

Krohn, W.B. 2002. Successful integration of GAP databases into town planning: The Maine experience. Gap Analysis Bulletin No. 11, pp 44-47.

McCalmon, M., and J. Jacobson. 2004, Pierce County Biodiversity Network assessment, August. Report to Pierce County Council, Pierce County, Washington.

NatureMapping, 2006. *Bainbridge Island*. Washington NatureMapping Program. Accessed February 2007 at http://depts.washington.edu/natmap/projects/bainbridge

Pierce County, 2004. *Protecting biodiversity in Pierce County through open space planning.* Pierce County Planning and Land Services. Accessed February 2007 at http://www.co.pierce.wa.us/pc/services/home/property/pals/other/biodiversity.htm

Scott, J.M. 2000. Preface. *Gap Analysis Handbook*, version 2.0. National Gap Analysis Program, Moscow, ID.

Stevenson, M. 1998. Applying gap analysis to local land use planning in Washington State. *Gap Analysis Bulletin No. 7*, p. 30-32.

Svancara, L. 2000. Creating a conservation plan for Latah County, Idaho. *Gap Analysis Bulletin No. 9*, p. 54.

Washington Biodiversity Project. 2006. Bainbridge Island selected for international biodiversity project. Accessed February 2007 at http://www.biodiversity.wa.gov/ourbiodiversity/bainbridge.html

Wild, C. 2002. *San Francisco Bay Gap Analysis: A preliminary assessment of priorities for protecting natural communities*. California State Coastal Conservancy, Oakland, CA.

# Biodiversity Data for Land Conservation: A Case Study

Klugh Jordan[1]

## Introduction

The Eno River Association is a land trust, educational and advocacy organization. We work in a single watershed in the Piedmont region of North Carolina (NC) where our mission is to conserve and protect the natural, historical, and cultural resources of the Eno River Basin. Our organization began around the creation and expansion of a linear State Park along the river. As that vision has been realized, we have expanded our efforts to include private land conservation throughout the rest of the watershed. This broader focus requires new data to identify critical conservation areas beyond the main stem of the river.

There is a real need for widely recognized biodiversity data. We use it whenever possible at two different stages of our conservation work: as an input during the planning stage for prioritizing the most critical areas in which to work, and as a demonstration to funding sources and the public of the value of the projects that we have already undertaken.

Two programs that provide such data are the Natural Heritage Program and the Gap Analysis Program (GAP). While North Carolina already has a strong Natural Heritage Program, we look forward to the availability (expected this year) of state and regional GAP data as a complement.

Two contrasting project areas provide examples of the differing ways these data are useful for land trusts working on conservation planning.

## Diabase Sills Project

In 2003, we formed a partnership with the NC Department of Agriculture's Plant Conservation Program and the NC Botanical Garden to acquire and restore land along a short stretch of the river where Diabase soils support several plant communities that are rare for our region. More than one dozen listed species occur on properties in the area, including glade wild quinine (*Parthenium auriculatum*), prairie wild blue indigo (*Baptisia minor*), tall larkspur (*Delphinium exaltatum*), and the federally endangered smooth coneflower (*Echinacea laevigata*). These plants require direct sunlight to thrive, so we have undertaken prescribed burning and selective thinning to extend suitable habitat from the road sides, where the plants were originally found, into the interiors of the properties.

The project area is small—less than 4 square miles—so we already had a fairly comprehensive knowledge of the critical tracts that we wanted to acquire. We looked to biodiversity data from the State's Natural Heritage Program to identify significant habitats and element occurrences (actual and precise locations of listed species occurrences), which helped with our prioritization. At the time we began our project, the area had 15 element occurrences of distinct populations of listed plants. Today, there are five times that many element occurrences and parts of the region have been designated as Significant Natural Heritage Areas of both state and national importance. As useful as the Natural Heritage data was for identifying the parcels of highest priority, it has been equally valuable in demonstrating the project's importance to potential funding sources. Several of the State's conservation trust funds use Natural Heritage data as a measure for distinguishing between projects applying for support.

Natural Heritage Program data, by circumstance, are often limited to public lands where ecologists are able to gain the access necessary to make observations and report their findings. Therefore, it worked in our favor that this project area also contains a significant amount of public land. However, the element occurrences that our group has identified and reported since we began the project have only served to further highlight the importance and success of our land protection and restoration work.

## Upper Eno Project

Another primary area where we focus our work has a considerably different set of circumstances. This project area covers more than 50 square miles and is almost entirely privately owned agricultural and rural residential land, although development is increasing. Although Natural Heritage Program data are sparse for the project area, it is largely confined to the publicly accessible river corridors, and of course, it only addresses habitat for rare species.

[1] Eno River Association, Durham, North Carolina.

Our objectives for this project differ as well. Here, we are specifically interested in protecting forested buffers for water quality and wildlife habitat along the Eno River and its tributaries, but more generally in conserving the open space and rural nature of the region. In most cases, we favor acquiring conservation easements over purchasing land outright. With a conservation easement, we know that the land is protected from development and with sufficient vegetated stream buffers, but the land can remain in private hands and we are not taking on management responsibilities ourselves.

Criteria we use to plan our work here include: existence of important ecosystems, habitat and geologic characteristics, wetlands, floodplains, steep slopes near streams and rivers, and significant areas of forest or prime agricultural land. GAP data provides an important large scale look at many of these important factors, and helps us narrow our prioritization focus to these data capture areas that support not only endangered species, but that serve as expansive habitat for common species as well. Finally, by looking at land cover changes over time, GAP data can provide a powerful view of development trends, including fragmentation and the spread of impervious surfaces (roads, parking lots, etc.) to indicate areas of greatest risk to development.

There is a significant amount of information that GAP data can provide to land trusts engaged in conservation planning. While land trusts vary in their GIS and data analysis capabilities, making GAP data available and accessible for local conservation planning can help guide land trust acquisitions to the most critical areas in terms of existing resources and impending threats.

# LAND COVER

# Land Cover Map for Map Zones 8 and 9 Developed from SAGEMAP, GNN, and SWReGAP: A Pilot for NWGAP

James S. Kagan[1], Janet L. Ohmann[2], Matthew Gregory[3] and Claudine Tobalske[1]

## Introduction

As part of the Northwest Gap Analysis Project (NWGAP), a land cover map was generated for U.S. Geological Survey (USGS) Map Zones 8 and 9, which covers most of eastern Washington, eastern Oregon, and parts of western Idaho and northern Nevada. The map was derived from two primary components. The first was a combination of two large regional datasets: SAGEMAP covering eastern Oregon and Washington and southern Idaho, based on the 2000–2001 MLRC imagery, and SWReGAP covering the northern Nevada part of Map Zone 9. SAGEMAP and the Southwest Regional Gap Analysis Project (SWReGAP, Lowry et al. 2005) used regionally consistent geospatial data (Landsat ETM+ imagery and DEM derivatives), similar field data collection protocols, a standardized land cover legend, and a common modeling approach (decision tree classifier). The second component was a Gradient Nearest Neighbor (GNN) (Ohmann and Gregory 2002) modeling effort developed for forests and some woodlands, based on the network of forest vegetation plots in the region. These projects were integrated and improved to create the final maps, which provide information beyond what is contained in typical land cover maps. The goal of the project was to develop a land cover map and database for the area that included as much information as possible on the status of the vegetation and habitats, building from available information but applying some new techniques.

## Classification Methods

SWReGAP mapped land cover for Colorado, Utah, Nevada, New Mexico, and Arizona, and was an important component of our project. The availability of the SWReGAP map and the decline of the greater sage grouse (*Centrocercus urophasianus*) inspired Steve Knick and the USGS Great Basin Information Program to start the SAGEMAP project, to classify and map sagebrush and steppe vegetation in the West based on SWReGAP methods. For SAGEMAP, where shrub cover explains much of the variation in plant communities, a total shrub cover grid was developed to distinguish shrubland, steppe, and grassland vegetation. Following similar methodology used in trial regions of SWReGap (Jennings et al. 1993, Huang et al. 2002) and by Washington Fish and Wildlife (Jacobson et al. 2000), overall percentage of shrub cover was estimated for each training site. Total shrub coverage was represented as a continuous variable but reclassified to five categorical types following guidelines suggested by LandFire (Rollins and Frame 2006). The continuous surface was generated using a separate classification and regression tree (CART) model.

All mapping efforts used classes based on the NatureServe Terrestrial Ecological Systems (ES) Classification (Comer et al. 2003), which focuses on natural and semi-natural ecological communities. For all mapping efforts, altered and disturbed land cover and land use classes were considered separately, based where possible on National Land Cover Database classifications and maps for nonforested areas, and on the GNN models for forested areas. Most new work involved modeling forest areas using GNN and non-vegetated and riparian ESs using CART.

## Gradient Nearest Neighbor (GNN) Imputation

The Gradient Nearest Neighbor (GNN) method (Ohmann and Gregory 2002) uses multivariate gradient modeling to integrate data from regional grids of field plots with satellite imagery and mapped environmental data. A statistical model

[1] Institute for Natural Resources and Oregon Natgural Heritage Information Center, Oregon State University, Portland, Oregon.

[2] Pacific Northwest Research Station, USDA Forest Service, Corvallis, Oregon.

[3] Department of Forest Service, Oregon State University, Corvallis, Oregon.

is used to impute a suite of fine-scale vegetation variables to each pixel in a digital map, and regional maps then can be created for any vegetation attributes. Key advantages of GNN maps are: efficiency in mapping large areas at fine spatial and attribute resolution; analytical flexibility provided by vegetation data at the basic level of tree species, sizes, and densities; representation of full range of variability in regional maps; and maintenance of covariance structure (species co-occurrence) of plant communities. Until now, most GNN projects have emphasized mapping of forest structure. In this project we developed two GNN models: one emphasizing species composition, which we used to map forested ESs; and one emphasizing forest structure, which we used to map several forest structure 'modifiers' of the forested ESs (for example, average tree size, canopy cover). The vegetation data used in GNN modeling were from ~4,000 regional forest inventory plots installed by the Forest Service and Bureau of Land Management (BLM): the Forest Inventory and Analysis Program of the Pacific Northwest Research Station, and Current Vegetation Survey plots of the Pacific Northwest Region and BLM. For spatial data, we used mapped information on climate and topography in addition to Landsat imagery.

## Results and Discussion

### Integrated Map of Ecological Systems for Map Zones 8 and 9

We combined the GNN and SAGEMAP component grids into a single map of ESs for Map Zones 8 and 9. An example landscape in the Blue Mountains ecoregion of eastern Oregon is shown in Figure 1. We also developed several modifiers of the ESs that we provided as separate grids: forest characteristics from GNN (multiple attributes joined to a single grid), and cover of shrubs, annual grasses, and perennial grasses from SAGEMAP. Examples of modifiers also are shown in Figure 1.

### Mapping Forested Ecological Systems with GNN

We developed two GNN-based models: (1) a 'species model' used to map 19 forested ESs in Map Zones 8 and 9 (Table 1), and (2) a 'structure model' used to map modifiers of the ESs that characterize forest structure, such as average tree diameter and tree canopy cover. We developed several accuracy assessment products to accompany the maps, addressing local (plot) and regional scales.

**Table 1.** Forested Ecological Systems in Map Zones 8 and 9 that were mapped using GNN.

[**ESLF,** Ecological System Life Form. **Ecological System geographic abbreviations:** CB, Columbia Basin; CP, Columbia Plateau; EC, Eastern Cascades; IMB, Inter-Mountain Basins; MRM, Middle Rocky Mountain; NP, North Pacific; NRM, Northern Rocky Mountain; RM, Rocky Mountain]

| ESLF | Ecological System |
|---|---|
| 4103 | NRM Western Larch Savanna |
| 4104 | RM Aspen Forest and Woodland |
| 4204 | CP Western Juniper Woodland and Savanna |
| 4205 | EC Mesic Montane Mixed-Conifer Forest and Woodland |
| 4228 | NP Mountain Hemlock Forest |
| 4232 | NRM Dry-Mesic Montane Mixed Conifer Forest |
| 4233 | NRM Subalpine Woodland and Parkland |
| 4234 | NRM Mesic Montane Mixed Conifer Forest |
| 4237 | RM Lodgepole Pine Forest |
| 4240 | NRM Ponderosa Pine Woodland and Savanna |
| 4242 | RM Subalpine Dry-Mesic Spruce-Fir Forest and Woodland |
| 4243 | RM Subalpine Mesic Spruce-Fir Forest and Woodland |
| 4244 | RM Subalpine-Montane Limber-Bristlecone Pine Woodland |
| 4266 | MRM Montane Douglas-fir Forest and Woodland |
| 4267 | RM Poor Site Lodgepole Pine Forest |
| 4301 | EC Oak-Ponderosa Pine Forest and Woodland |
| 4303 | IMB Mountain Mahogany Woodland and Shrubland |
| 9170 | CB Foothill Riparian Woodland and Shrubland |
| 9190 | NP Hardwood-Conifer Swamp |

The predicted spatial distribution of ESs from GNN depends largely on how the training plots are classified into ESs. Because ESs are defined floristically based on existing vegetation, we relied on relative abundances of tree species to classify the plots, plus information on potential vegetation type and ecoregion as needed. We did not use data on understory vegetation (shrub and herb species) because these data were not yet available in a standardized database. We have now obtained these data and are using them in Map Zones 2 and 7.

In Map Zones 8 and 9, many ESs intermingle in the landscape (Figure 1*B*) as mosaics determined by interacting influences of physical environment and disturbance. This variation often is at a very fine scale, with field plots encompassing more than one ES. For this project we chose not to recognize within-plot variation in vegetation and ESs, and analyzed field plots as intact units. Because of this fine-scale variation, and the fact that classification to an ES often hinges on small shifts in relative abundance of the same few species in mixed-conifer forests, it is not surprising that the GNN maps contain some 'confusion' among these ESs. We conveyed this by presenting 'fuzzy' accuracy assessment statistics, where certain ESs are considered to be similar

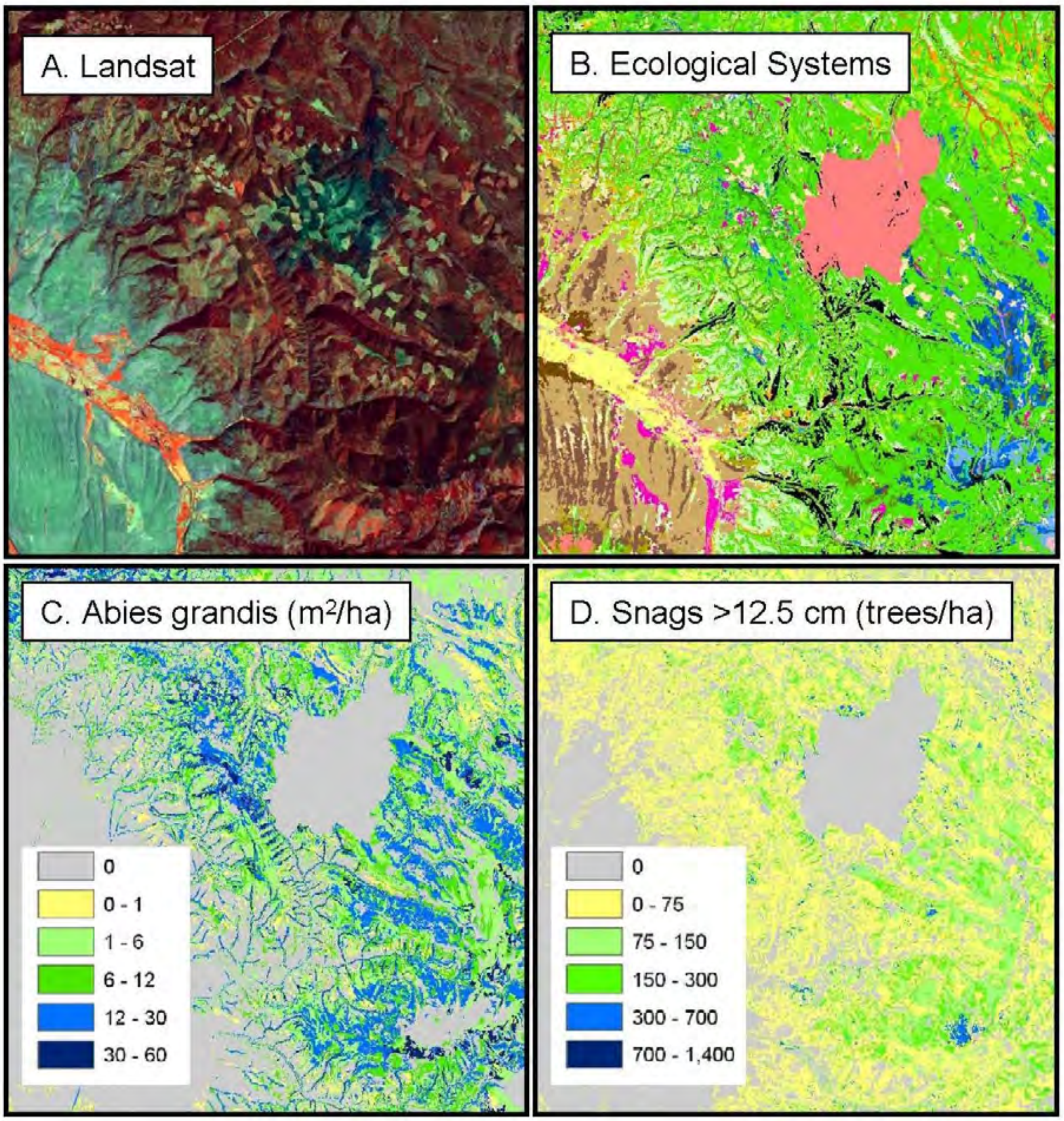




**Figure 1.** An example landscape in the John Day basin in eastern Oregon (location shown as blue square in inset map). *A*. Landsat imagers, summer 2000. *B*. Ecological Systems (legend not shown) combined from GNN and SageMap. *C*. Abundance (basal area) of Abies grandis from GNN species model. *D*. Snag density from GNN structure model.

and hence 'correct' in a fuzzy sense. We also had difficulty mapping several ESs that are rare in the landscape and lack sufficient plot data, primarily riparian and other hardwood types such as aspen and mountain mahogany. We applied some local editing to the final integrated forest/nonforest ES map to 'burn in' some of these ESs from the SAGEMAP or SWReGAP grids.

Another difficulty that faces all land cover mapping projects relying on Landsat imagery is the discrimination of forest from nonforest. Disturbed forest sites (for example, recently clearcut or burned) are not readily distinguished from true shrublands or grasslands, and areas of naturally sparse trees (for example, juniper woodland) cannot be distinguished from grasslands and shrublands that lack tree cover. We expect there is confusion in our maps among the forest and nonforest ESs (as can be seen in Figure 1), but this has not been quantified.

We used Landsat-derived variables in the GNN model of forest structure but not in the GNN species model. Prediction accuracy for individual species and plant communities (and hence ESs) was actually reduced when Landsat variables were included. This is because a nearest-neighbor plot can be selected for a map pixel based on similarity in forest structure (the primary forest vegetation 'signal' in the Landsat data) whereas species composition may be a poor match for the location. In the GNN model of forest structure, including two-date Landsat variables resulted in slightly better accuracy for most measures of forest structure, but introduced fine-scale heterogeneity ('salt-and-peppering') to the maps that we deemed undesirable. Until we can explore the reasons for this result, we opted to provide a GNN map of forest structure modifiers based on single-date (summer) imagery.

## Mapping Non-Vegetated Ecological Systems

An interesting finding of our project was the improvement in SAGEMAP data gained by mapping the non-vegetated ESs. The SAGEMAP plot locations were selected based on a landscape analysis of variables (climate, topography, elevation, and distance from roads) thought to be related to ES distributions. Non-vegetated areas were not sampled by SAGEMAP nor SWReGAP, which focused on vegetated areas. In particular, mostly barren lava flows, cliffs and canyons, ash beds, playas, and sand dunes were not sampled or mapped. For NWGAP, we modeled these areas separately, generating points for modeling and accuracy assessment using ancillary data. For example, ash beds provide habitat for a large number of rare, endemic plant species, and contain points from threatened and endangered species databases. This allowed us to identify many small ash beds on the imagery, which we used as training points. Cliffs and canyons were modeled using new 10-meter digital elevation models, and the results corresponded exceptionally well to the large known cliff and canyon areas. The sum total of these non-vegetated areas is not very large, but their inclusion greatly improves the map's depiction of wildlife habitat. The accuracy of mapping these non-vegetated types is high enough (97 percent, Kappa of 96 percent; Kagan et al. 2006), and the time demands of independently modeling them is low enough, that adding this step to mapping arid landscapes seems exceptionally useful.

## Mapping Riparian, Forest Structure, Weeds, Shrub Cover, and Conditional Variables

We were fortunate to have more than 3,000 riparian plots from a 12-year interagency effort to attribute riparian plant associations to different basins, stream orders, and valley types. Using data on the plant communities from the ESs and knowledge of the riparian vegetation, we were able to attribute the riparian plots to an ES and develop a separate riparian model and map. To model riparian ESs, we used a buffered, 1:24,000 layer for perennial streams, the valley profile created from a 10-meter DEM, the Landsat imagery, and a large riparian plot database. While the riparian grid has not been widely tested, it initially looks quite good.

By using GNN to develop modifiers of forested ESs, and by including the weed and shrub covers from SAGEMAP, we were able to provide new kinds of information describing the condition of many mapped ESs. This information is particularly important because habitat condition describes how wildlife use areas as strongly as the ESs themselves. For instance, to map a species such as the Vaux's swift, which require older trees and snags, grids showing average diameter or abundance of snags and woody debris are more useful than the ES maps showing what forest type is present. Initially, we suggested that it might be relatively simple to integrate the diverse information describing the condition of habitats into a set of modifiers. However, it appears that turning the ancillary information into a habitat suitability index usable over the five-state NWGAP area is likely to be very difficult, because suitability for different species varies, as does suitability for a single species over a very large geographic area. This clearly indicates the need for standards.

# References Cited

Comer, P., D. Faber-Langendoen, R. Evans, S. Gawler, C. Josse, G. Kittel, S. Menard, S. Pyne, M. Reid, K. Schulz, K. Snowand, and J. Teague. 2003. *Ecological systems of the United States: A working classification of U.S. terrestrial systems*. NatureServe, Arlington, Virginia.

Huang, C., B. Wylie, C. Homer, L. Yang, and G. Zylstra,. 2002. Derivation of a Tasseled cap transformation based on Landsat 7 at-satellite reflectance. *International Journal of Remote Sensing* 23(8): 1741-1748.

Jacobson, J.E. and M.C. Snyder. 2000. *Shrubsteppe mapping of eastern Washington using Landsat satellite thematic mapper data*. Washington Department of Fish and Wildlife, Olympia, WA. Available from http://wdfw.wa.gov/wlm/research/papers/shrubsteppe_map/shrubsteppe_map.pdf

Jennings, M.D. 1993. Natural terrestrial cover classification: Assumptions and definitions. *Gap Analysis Technical Bulletin 2*. Idaho Cooperative Fish and Wildlife Research Unit, University of Idaho, Moscow.

Kagan, J.S., J.A. Ohmann, M.J. Gregory, C. Tobalske, J.C. Hak, and J. Fried. 2006. *Final report on land cover mapping methods, map zones 8 and 9*, PNW ReGAP. Institute for Natural Resources, Oregon State University, Corvallis, OR.

Lowry, J.H, Jr., R.D. Ramsey, K. Boykin, D. Bradford, P. Comer, S. Falzarano, W. Kepner, J. Kirby, L. Langs, J. Prior-Magee, G. Manis, L. O'Brien, T. Sajwaj, K.A. Thomas, W. Rieth, S. Schrader, D. Schrupp, K. Schulz, B. Thompson, C. Velasquez, C. Wallace, E. Waller and B. Wolk. 2005. *Southwest Regional Gap Analysis Project: Final report on land cover mapping methods*, RS/GIS Laboratory, Utah State University, Logan, Utah.

Ohmann, J.L., and M.J. Gregory. 2002. Predictive mapping of forest composition and structure with direct gradient analysis and nearest neighbor imputation in coastal Oregon, USA. *Canadian Journal of Forest Researc*h 32:725-741.

Rollins, M.G. and C.K. Frame. 2006. *The LANDFIRE prototype project: nationally consistent and locally relevant geospatial data for wildland fire management*. Gen. Tech. Rep. RMRS-GTR-175. Fort Collins: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 416 p.

# Testing the Utility of High Resolution SPOT Data to Determine Physiognomic Classes for Modeling Ecological Systems in the Northern Rockies Ecoregion

By Anne Davidson[1]

## Introduction

The Northwest Gap Analysis Program (NWGAP) is mapping existing land cover across Idaho, Oregon, Montana, Washington, and Wyoming (GAP 2007). We are using NatureServe's ecological systems as our classification. Comer et al. (2003) define ecological systems as "systems that represent recurring groups of biological communities that are found in similar physical environments and are influenced by similar dynamic ecological processes, such as fire or flooding."

The vegetation mapping effort for NWGAP is divided up by USGS map zones and comprise three separate mapping efforts. The National Gap Analysis Program (GAP) office in Moscow, ID has been mapping zones 10, 19, and 21 while the other zones are being mapped by Sanborn Map Company, U.S. Department of Agriculture Forest Service, and Oregon State University.

The initial models for zones 10, 19, and 21 are being developed through Classification and Regression Tree (CART) modeling. Specifically the mapping process involves Classification Tree (CT) modeling (Lowry et al. 2007). The process of CT modeling is iterative, with the analyst evaluating output, and then changing the predictive layers or restricting the modeling of an Ecological System to a particular area, then rerunning the model. Once optimal output has been achieved through CT, conditional models based on expert knowledge of the area will be used to further improve and refine the initial CT developed product.

I am exploring the use of physiognomic classes during the CT modeling process to restrict ecological system assignments to areas with the appropriate vegetation growth form identified. This creates a coarse thematic land cover map at the physiognomic class level that can be used to restrict subsequent models aimed at mapping at the finer thematic level of ecological systems. For example, this approach ensures that forested ecological systems are not mapped in nonforested areas.

I evaluated the utility of SPOT data as a predictor of physiognomic class in the Northern Rockies ecoregion, which covers the northern part of Zone10. This is a 10,000,000 hectare area of Northeastern Washington, Northern Idaho, and Northwestern Montana. I am using 2.5 meter SPOT (SPOT 2007) data available across Idaho (Interactive Numeric and Spatial Information Date Engine 2007) for identifying physiognomic class distributions. These high resolution data are used to visually distinguish trees, shrubs, grassland-steppe-herbaceous, and sparse areas from each other. I developed a methodology for summarizing the 2.5 meter SPOT data to 30 meters, the resolution at which NWGAP ecological systems are being mapped. I then extrapolated the predicted physiognomic classes to areas in Washington and Montana where free SPOT data were not available. The accuracy of the predicted physiognomic classes was assessed using field data containing known physiognomic classes collected in summer 2005 and 2006.

## Methods

### Obtaining Training Samples from SPOT Imagery for Landsat Classification

The SPOT data for Idaho are distributed in 1:24,000 quad tiles. Four quads in the Idaho part of the Northern Rockies ecoregion were selected based on their diversity of physiognomic classes. The data contain 2.5 meter pixels with values ranging from 0 (black) to 255 (white). Forested areas have values close to 0, while barren areas were closer to 255 (Table 1). I established 4 physiognomic classes based on an exploratory analysis of areas familiar to me (Table 1). Each quad of SPOT data was broken into four grids with each grid representing the distribution of one physiognomic class. A 'No Data' value was assigned to all areas not in the physiognomic

[1] Gap Analysis Program, University of Idaho, Moscow, Idaho.

class represented by the grid. To rescale the data to 30 m, the resolution for NWGAP Ecological Systems mapping, I used the ArcGIS aggregate command (Environmental Systems Research Institute 2007) to count the number of 2.5 m cells in each 30 m cell for each physiognomic class. I then converted these counts to percentages.

**Table 1.** Spectral values used to assign physiognomic classes

| Values | Physiognomic class |
|---|---|
| 0–95 | Forest |
| 96–140 | Shrub |
| 141–200 | Grass/steppe |
| 200–255 | Barren |

To determine the physiognomic composition of each 30-m cell, I combined the information contained in each of the four physiognomic percent grids into one grid. The percent grids were reclassed (Table 2) and summed together. The result was a 30 m resolution grid with values ranging from 1,116 (almost all barren) to 6,111 (almost all forest).

**Table 2.** Values used to reclass and combine physiognomic class grids.

| Percent | Forest | Shrub | Grass/steppe | Barren |
|---|---|---|---|---|
| 0–9 | 1,000 | 100 | 10 | 1 |
| 10–24 | 2,000 | 200 | 20 | 2 |
| 25–39 | 3,000 | 300 | 30 | 3 |
| 40–64 | 4,000 | 400 | 40 | 4 |
| 65–84 | 5,000 | 500 | 50 | 5 |
| 85–100 | 6,000 | 600 | 60 | 6 |

Areas comprised primarily by a single physiognomic class (i.e., 'pure') were selected as training data for CART modeling and used to predict physiognomic classes across the ecoregion. Rules were used to assign training cells to a physiognomic class (Table 3) and once a cell was assigned it was not influenced by subsequent rules. Cells with values that did not match these rules were considered mixed physiognomy areas and were not used as training data.

**Table 3.** Cell values selected for use as training data and order applied.

| Cell Value (x=any value) | Physiognomic class | Rule order |
|---|---|---|
| 6xxx or 5xxx | Forest | 1 |
| 4xxx | Woodland | 2 |
| x6xx or x5xx or x4xx | Shrub | 3 |
| xx6x or xx5x or xx4x | Grass, steppe | 4 |
| xxx6 or xxx5 or xxx4 | Barren | 5 |

## Using CART to Develop a Physiognomic Class Map Across an Ecoregion

A CT model was used to map the physiognomic classes, across the entire Northern Rockies ecoregion, using the training data obtained from the SPOT imagery. I used the Rulequest C5 classifier with the ERDAS NLCD extension (Earth Satellite 2003; RuleQuest Research 2004). Training data selected in the previous step were used as independent data. I defined three dates of 2001 Landsat imagery, tasseled cap data derived from the three dates of imagery, slope, elevation, and aspect as dependent variables in my analysis.

## Validation of Physiognomic Class Map Using Field Data

During summers 2005 and 2006, vegetation training information was collected including vegetative species, canopy cover, ecological systems, and physiognomic class. Field data were collected by identifying areas of homogenous vegetation that were at least 90 by 90 m. These areas were located on Landsat imagery and hand digitized into a polygon layer. Vegetation information was recorded in a Microsoft Access database linked to a GIS layer. These data were used to evaluate the predictive ability of the physiognomic class model.

The physiognomic class information was used to evaluate the modeled physiognomic class map. The representation of modeled physiognomic classes in the polygons based on field-collected training data was calculated using the zonal statistics function of ArcGIS (Earth Sciences Research Institute 2007). This provided the number of physiognomic classes in each field-derived polygon and the dominant physiognomic classes.

## Results and Discussion

The Northern Rockies Ecoregion map of physiognomic classes was dominated by forest and woodland classes (67 percent), with barren areas predicted to comprise only 2.2 percent of the area (Table 4). Visually evaluating the map with Landsat data or higher resolution imagery indicated the physiognomic class model had assigned most areas to the appropriate physiognomic class. Physiognomic classes that were most similar such as forest and woodland or barren and grass caused the most confusion.

**Table 4.** Representation of physiognomic classes in the Northern Rockies Ecoregion.

| Physiognomic class | Area of Northern Rockies Ecoregion (hectares) | Area of Northern Rockies Ecoregion (percent) |
|---|---|---|
| Barren | 223,510 | 2.2 |
| Grass/steppe | 1,859,100 | 18.6 |
| Shrubland | 1,216,900 | 12.2 |
| Woodland | 3,280,000 | 32.8 |
| Forest | 3,421,700 | 34.2 |

I compared the dominant modeled physiognomic class (map data) in each field derived polygon to the physiognomic class recorded in the field (reference data; Table 5).

The greatest confusion was between classes of similar physiognomies and spectral values, for example, forest and woodland or barren or grass. The shrub class was the least accurately predicted class; it was commonly confused with the grass and woodland classes (Table 5). This was likely due to structural and spectral similarities between the three classes.

Ecologically, the boundaries between the physiognomic classes are fuzzy, shrublands transition into woodlands and woodlands transition into forests on the landscape. In acknowledgement of the fuzziness of the distinction between classes, the accuracy of the classes was then evaluated based on grouping of similar physiognomic classes (Table 6).

Grouping classes with similar physiognomies improved accuracies substantially (Tables 5 and 6). This indicates that grouped physiognomic classes may be more appropriate for restricting finer-level classifications with the CT than the individual physiognomic classes. For example a forest, non-forest map may be the most appropriate use of the modeled physiognomic classes. The high resolution SPOT data that was used as an input into this physiognomic class model should make possible a more accurate break between forest and non-forested areas than is possible with coarser data such as the National Land Cover Database (Vogelman et al. 2001). This would result in a better representation of Ecological Systems and a more accurate map of the land cover of the Northwest. To further evaluate this, a comparison of the accuracy ecological systems modeled using a SPOT physiognomic class group break, a NLCD physiognomic class break, and no physiognomic class break will be conducted during the Northwest land cover mapping project.

**Table 5.** Confusion matrix for physiognomic classes.

| | | Reference data | | | | | Column total | Number correct | Users accuracy |
|---|---|---|---|---|---|---|---|---|---|
| | | Barren | Grass | Shrub | Woodland | Forest | | | |
| Map data | Barren | 6 | 3 | 4 | 0 | 0 | 13 | 6 | 46.2 |
| Map data | Grass/steppe | 8 | 61 | 20 | 42 | 13 | 144 | 61 | 42.4 |
| Map data | Shrub | 0 | 9 | 44 | 44 | 24 | 121 | 44 | 36.4 |
| Map data | Woodland | 1 | 4 | 31 | 132 | 169 | 337 | 132 | 39.2 |
| Map data | Forest | 1 | 0 | 13 | 111 | 445 | 570 | 445 | 78.1 |
| | Row totals | 16 | 77 | 112 | 329 | 651 | | | |
| | Number correct | 6 | 61 | 44 | 132 | 445 | | | |
| | Producer’s accuracy | 37.5 | 79.2 | 39.3 | 40.1 | 68.4 | | | |

**Table 6.** Accuracies for combined physiognomic class groups.

| Combined class | Producers accuracy (percent) |
|---|---|
| Barren and grass/steppe | 83.8 |
| Woodland, forest and shrubland | 92.7 |
| Barren, grass and shrubland | 75.6 |
| Woodland and forest | 89.6 |

## References Cited

Comer, P., D. Faber-Langendoen, R. Evan, S. Gawler, C. Josse, G. Kittel, S. Menard., M. Pyne, M. Reid, K. Schulz, K. Snow, and J. Teague. 2003. *Ecological Systems of the United States: A Working Classification of U.S. Terrestrial Systems*. NatureServe, Arlington, Virginia.

EarthSatellite. 2003. *CART Software User's Guide*, prepared by EarthSatellite Corporation for the US Geological Survey in support of the National Land Cover Database (NLCD).

Earth Sciences Research Institute. 2007. ArcMap Version 9.2. Available: http://www.esri.com

Gap Analysis Program. 2007. *The Gap Analysis Program-Keeping Common Species Common*. Available at: http://gapanalysis.nbii.gov/

Interactive Numeric and Spatial Information Data Engine (INSIDE Idaho). 2007. SPOT Imagery for Idaho. Available at: http://inside.uidaho.edu/geodata/SPOT/index.htm

Lowry, J.H. Jr., R.D. Ramsey, K. Boykin, D. Bradford, P. Comer, S. Falzarano, W. Kepner, J. Kirby, L. Langs, J. Prior-Magee, G. Manis, L. O'Brien, K. Pohs, W. Rieth, T. Sajwaj, T.S. Schrader, D. Schrupp, K. Schulz, K.A. Thomas, B. Thompson, C. Velasquez, C. Wallace, E. Waller and B. Wolk. 2007. Mapping meso-scale land cover over very large geographic areas within a collaborative framework: A case study of the Southwest Regional Gap Analysis Project (SWReGAP). *Remote Sensing of the Environment*. Vol. 108:59-73.

RuleQuest Research. 2004. See-5 Info. Available at: http://www.rulequest.com/index.html

SPOT Image Coorporation. 2007. SPOT Images, products and images. Available at: http://www.spot.com

Vogelman, J.E., S.M. Howard, L. Yang, C.R. Larsen, B.K. Wylie, and N. Van Driel. 2001. *National Land Cover Database 2001 (NLCD)*. U.S. Geological Survey Earth Resources Observation Systems (EROS) Data Center.

# A Habitat Modeling Database for the Southwest Regional Gap Analysis Project

Kenneth G. Boykin[1] and Robert A. Deitner[1]

## Introduction

The Southwest Regional Gap Analysis Project (SWReGAP) created predictive suitable habitat models for 819 terrestrial vertebrate species within the five Southwestern States of Arizona, Colorado, Nevada, New Mexico, and Utah. The necessity of capturing the data and coordinating the effort between five states led to the development of a regional database system that collected wildlife habitat relationships, created habitat models, and provided for model modification. The objective was to provide a dynamic mapping application that met objectives of the SWReGAP project and potential end users. Database design was further driven by the need for documenting model attributes and model modifications.

The number of modeled species compounded both the effort and complexity needed for the database and modeling process. The database system documents wildlife habitat relationships developed from 13 core datasets including land cover, landforms, elevation, aspect, slope, soils, and distance to hydrological features (springs, streams, and lakes). The system also documents species ranges to 8-digit hydrologic cataloging units (HUCs) and mountain ranges for specific species. In addition, a standard set of state and regional references, available peer-reviewed articles, and grey literature had to be captured.

The database system required several additional functional characteristics. It had to allow multiple users to edit data simultaneously, provide users with common biological terminology for use in model creation and editing, generate reports of model inputs, and provide a method to compile the data into a modeling language for use in habitat model production. The database system was created in Microsoft Access (Microsoft Corporation 2002) using Structured Query Language (SQL) and three linked databases. The system also uses ArcGIS (Environmental Systems Research Institute 2005) to produce spatial representations of input data. User interaction with the dataset was through a FrontEnd (Boykin et al. 2006) suite of programs that managed the data in the DataStore (Boykin et al. 2006), compiled GIS code, and executed the code.

The FrontEnd database provided a method for creating and editing model inputs in plain language with user-friendly forms that provide an interface for model creation. Data were manipulated through standard SQL statements directed to the DataStore which provided the repository for data. This design allowed multiple FrontEnd instances to run simultaneously depositing information into one common DataStore.

Habitat modelers logged into project machines remotely to create and modify models. FrontEnd also created ERDAS graphical model (.gmd) (Leica 2003) files to provide the connection between the dataset and creation of GIS Models. The GISEngine (Boykin et al. 2006) was created to link to the DataStore such that batch modeling jobs could be created and monitored. To facilitate the modeling process, two model input datasets were created for the project with coarse resolution (240 m) for model review and fine resolution (30 m) for the final datasets. The 240-m dataset derived models were generated within 5 minutes whereas 30-m dataset derived models were generated in 1–3 hours.

## SWReGAP Application

SWReGAP model creation by 19 habitat modelers was facilitated by our database system. This system also provided a method for experts to review range information, habitat data, and resulting models for each species. A map of each species' range and a report describing the background and model attributes for each species were created directly from the database. The 240-m datasets provided the spatial model representation for review. Reviews were conducted in workshops or through the habitat modeling website with appropriate documentation. More than 80 reviewers from state and Federal wildlife agencies, university biologists, non-governmental organizations, and biological consultants evaluated 680 of 819 modeled species with a total of 1,023 reviews received. Reviews identified model errors and additional references and data to enhance models. This information was provided back to habitat modelers to modify the models based on this review in context with the regional habitat of the species.

[1] New Mexico Cooperative Fish and Wildlife Research Unit, New Mexico State University, Las Cruces.

The resultant models represent the first regional habitat models for terrestrial vertebrate species at this resolution for the American Southwest. The database and associated GIS tools provide end-users functionality and the ability for model modification. The database also provided a consistent guideline for model development with the recognition that each species and model was different.

## Future Applications

Models should be considered dynamic and the database provides two methods for model modification of the predicted habitat suitability models (suitable, unsuitable) developed for SWReGAP. The Erdas graphic model (.gmd) (Leica 2003) file can be modified in Erdas Imagine (Leica 2003) by changing input correlates or weighting correlates, if desired. Thus, both the database and .gmd file provide opportunities to incorporate habitat quality or preference.

Both methods also allow incorporation of other datasets that end-users may have specific to the area in question. The 8-digit HUC ranges can overpredict species ranges and finer scale HUCs (14-digit) may provide more accurate range delineation but increase delineation difficulty. Vegetation structure is an important habitat factor and the SWReGAP land cover legend provided partial structure (for example, woodland, forest, etc.), but finer structure or succession datasets were not available, nor were microhabitat features. Factors such as prey sources, competition, or predation also were not included. Climate datasets (for example, temperature, precipitation) were considered, but were not used because of incomplete species knowledge. Landscape metrics such as patch size, distance to habitat patches, and habitat edge were not included because of study scale and incomplete species knowledge, though patch size was captured in the database as a variable and could be included in future modeling efforts. These landscape metrics also could be used in a post-processing step with current models outputs. State references range from detailed, authoritative compilations on reptiles and amphibians (Degenhardt et al.1996) (Hammerson 1999), mammals (Fitzgerald et al.1994) and birds (Andrews and Righter 1992), while others were dated general works. Furthermore, future habitat modeling can include additional regional datasets (for example, Level IV Ecoregions) with the database or GMD files.

The database currently is being used to modify existing models specifically for Clark County Nevada through a collaborative effort between New Mexico State University and the U.S. Environmental Protection Agency. Using the database, species models for 37 species will be revisited and modified as appropriate and new models generated for the area of interest to the Multi-species habitat conservation plan within Clark County. Additionally, working with the New Mexico Department of Game and Fish, the database was used to modify a model for mountain lion to reflect primary, secondary, and tertiary ranges in New Mexico.

The database is the focus of ongoing workshops designed specifically for state wildlife agencies in 2007. Workshops are focused on setting up agency modeling platforms and providing the expertise to run models as needed with modifications. The next challenge for database use will include porting the database over into a web friendly platform such as MySQL (http://www.mysql.org/). This transition may provide added usability, as state agencies are limited because of software and funding.

## References Cited


Andrews, R., and R. Righter. 1992. *Colorado birds.* Denver Museum of Natural History, Colorado.

Boykin, K.G., B.C. Thompson, R.A. Deitner, D. Schrupp, D. Bradford, L. O’Brien, C. Drost, S. Propeck-Gray, W. Rieth, K. Thomas, W. Kepner, J. Lowry, C. Cross, B. Jones, T. Hamer, C. Mettenbrink, K.J. Oakes, J. Prior-Magee, K. Schulz, J.J. Wynne, C. King, J. Puttere, S. Schrader, and Z. Schwenke. 2006. *Predicted Animal Habitat Distributions and Species Richness.* Chapter 3 *in* J.S. Prior-Magee, ed. Southwest Regional Gap Analysis Final Report. U.S. Geological Survey, Gap Analysis Program, Moscow, ID. Available on-line at: http://fws-nmcfwru.nmsu.edu/swregap/

Degenhardt, W.G., C.W. Painter, and A.H. Price. 1996. *The amphibians and reptiles of New Mexico*. University of New Mexico Press, Albuquerque.

Environmental Systems Research Institute, Inc. 2005. ArcGis (Version 9.1), Redlands, California.

Fitzgerald, J.P., C.A. Meaney, and D.M. Armstrong. 1994. *Mammals of Colorado*. Denver Museum of Natural History, Denver and University Press of Colorado, Niwot, Colorado.

Hammerson, G.A. 1999. *Amphibians and reptiles of Colorado*. 2nd edition. University Press of Colorado, Niwot and Colorado Division of Wildlife, Denver.

Leica Geosystems *GIS and Mapping LLC*. 2003. ERDAS IMAGINE (Version 8.7). Heerbrugg, Switzerland.

Microsoft Corporation. 2002. Microsoft Office Access 2002. Microsoft Corporation.

This page intentionally left blank.

ANIMAL MODELING

# Novel Approaches to Mapping Vertebrate Occurrence for the Northwest Gap Analysis Project

Jocelyn Aycrigg[1] and Gary Beauvais[2]

## Introduction

The basic goal of the National Gap Analysis Program is to “keep common species common.” Modeling and mapping the occurrence of vertebrate species within a state or region are used to achieve this goal. During previous state GAP projects, standardized methods of modeling and mapping vertebrates were used (for example, Merrill et al. 1996). However, since those projects have been completed new modeling approaches have been developed, particularly inductive modeling approaches that integrate relatively well with advanced geographic information systems (GIS) (for example, Carpenter et al. 1993; Phillips et al. 2006; see Elith et al. 2006 for review).

The Northwest Gap Analysis Project (NWGAP), which includes Idaho, Montana, Oregon, Washington, and Wyoming, began in September 2004. Our objectives for this project include creating consistent and current data products that are repeatable and standardized, and of high utility to resource managers. To meet these objectives we are proposing some novel approaches to modeling and mapping vertebrate occurrence. Similar to other state and regional projects we will create a species list, collect species occurrence data, assemble habitat and environmental data, and conduct species modeling. Our novel approaches address who we are collaborating with to collect species occurrence data, what we are aiming to map, and how we are conducting the modeling. Throughout our work we intend to involve local resource managers and biologists as much as possible to increase the accuracy and utility of our data products.

## Who Will be Collecting Species Occurrence Data and Conducting Species Modeling?

We are working with the Natural Heritage Programs (NHP) in each of the 5 northwestern states to compile and organize all species occurrence data, provide local expertise and input into species modeling, and identify additional local and regional experts to involve in the project. The Northwestern NHPs are Montana Natural Heritage Program, Idaho Conservation Data Center, Washington Natural Heritage Program, Oregon Natural Heritage Information Program, and Wyoming Natural Diversity Database. The Wyoming Natural Diversity Database is acting as the central species modeling organization for NWGAP and is coordinating the activities of the other programs as well as producing final models and maps.

There are several advantages to collaborating with NHPs. First, each program contains a vast amount of existing expertise, occurrence data, and database and personnel infrastructure focused on describing and documenting the flora and fauna of their state, with special emphasis on species of conservation concern. Each program employs a lead zoologist who is recognized as an expert on the state fauna and environment, and who routinely collects, reviews, and summarizes vertebrate occurrence data. In effect, each NHP acts as a central clearinghouse for vertebrate occurrence data and status information for a given state.

Second, NHPs are responsible for managing species occurrence data only within their own state (although they regularly contact programs in neighboring states for information on species status, life history, and management).

[1] National Gap Analysis Program, University of Idaho, Moscow, Idaho.

[2] Wyoming Natural Diversity Database, University of Wyoming, Laramie, Wyoming.

By compiling regional occurrences for given species from five state-specific datasets, we can minimize the risk of obtaining duplicate records.

Third, each NHP uses a common database software, standards, and methods. This helps ensure that species occurrence records from different states have undergone similar quality control procedures, have similar content and format, and are easily integrated into a region-wide dataset. Species occurrences compiled for NWGAP will include a unique record identification, primary data source (for example, NHP zoologist, state biologist, etc.), genus and species, year of observation, month of observation, latitude/longitude of observation, and accuracy/precision of observation.

Fourth, the species occurrence data in each NHP are continually reviewed and quality-checked. Reviewing and quality-checking are necessary because individual species occurrences often are documented in many sources and NHPs commonly receive multiple submissions of the same observation. Without strict quality control individual species records could appear several times in the occurrence database.

This process minimizes the chance of duplicate records, which could bias subsequent estimates of a species distribution and (or) habitat use. Collaborating with NHPs for NWGAP ensures we will obtain a high quality, comprehensive compilation of occurrence records that requires minimal additional processing and screening.

Fifth, in addition to reviewing and quality checking the data, each NHP continually updates and maintains its occurrence database. Efficient access to updated data should make NWGAP products more dynamic. This will make re-running models for species with new occurrence data more feasible. By engaging NHPs as primary data sources, and employing more transparent and automated modeling methods, NWGAP cooperators should be able to update models and maps over short time frames.

## What Will Be Modeled?

We intend to map *range*, *distribution*, and *habitat quality* separately for each terrestrial vertebrate in the Northwest region (Figure 1). By providing this information we intend to make regional species models useful and applicable to local land and resource managers.

We consider a species' *range* as the total area occupied; similarly, the spatial limits within which a species can be found (Morrison and Hall 2002). Range maps, then, are typically coarse-grained depictions of a species' spatial patterning defined almost entirely by geographic space, with little consideration of underlying environmental features. We will produce range maps based on aggregations of all pre-defined map units known to be occupied by a given species. Map units for NWGAP range maps will be 10-digit Hydrologic Unit Codes (HUCs).

A species' *distribution* is defined as a finer-scale depiction of a species spatial patterning, which relies on identification of multivariate environments suitable for occupation by a given species; similarly, the "spread" or "scatter" of a species within its range (Morrison and Hall 2002). A species' distribution is a spatial subset of its range.

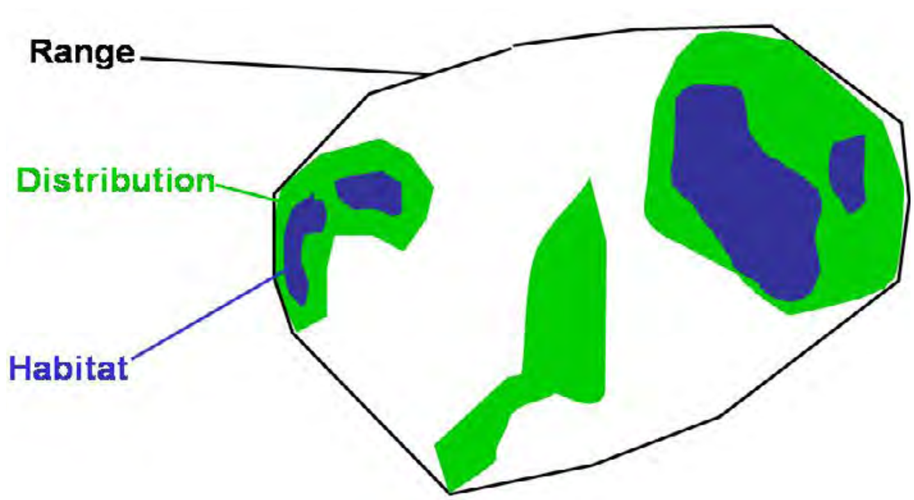



**Figure 1.** A hypothetical species' range, distribution, and habitat. Habitat is a spatial subset of distribution and distribution is a spatial subset of range.

In contrast to range maps, where map units are pre-determined blocks of geographic space that are occupied by individuals, distribution maps show the intersection of multiple environmental gradients that are potentially occupied by individuals (Beauvais and Master 2005). Distribution maps not only are finer in grain than range maps, but also depict more distinction between suitable and unsuitable environments.

A species' *habitat* is the combination of resources and conditions that promote occupancy, survival, and reproduction (Morrison and Hall 2002; Beauvais and Master 2005). Just as a species' distribution can be seen as a spatial subset of its range, a species' habitat is a spatial subset of its distribution. Habitat maps are inherently difficult to produce, especially for large areas, because the conditions that lead to positive rates of survival and reproduction vary at fine spatial and temporal scales, and often are not represented in large-extent digital maps. However, *habitat quality* maps, whereby different portions of a species' distribution are ordinally ranked (that is, high, medium, low) based on their predicted long term contribution to reproduction and survival can be produced by modifying distribution maps with additional information (Beauvais and Master 2005). We intend to produce habitat quality maps for terrestrial vertebrates in the Northwest by compiling expert opinion on environmental factors that correlate with rates of survival and reproduction, and modifying distribution maps accordingly.

## How Will Modeling Be Done?

Previous state and regional Gap projects have used a deductive, or "expert systems", modeling approach in which information about habitat associations are synthesized from experts and literature reviews (Figure 2). Types of habitat association data include land cover, elevation, soil, proximity to water, and climatic gradients. A predicted species distribution based on these habitat associations is made, and then intersected with and sometimes modified by species occurrence data. Species experts then review the draft distribution map, propose edits, and the map is revised to a final stage.

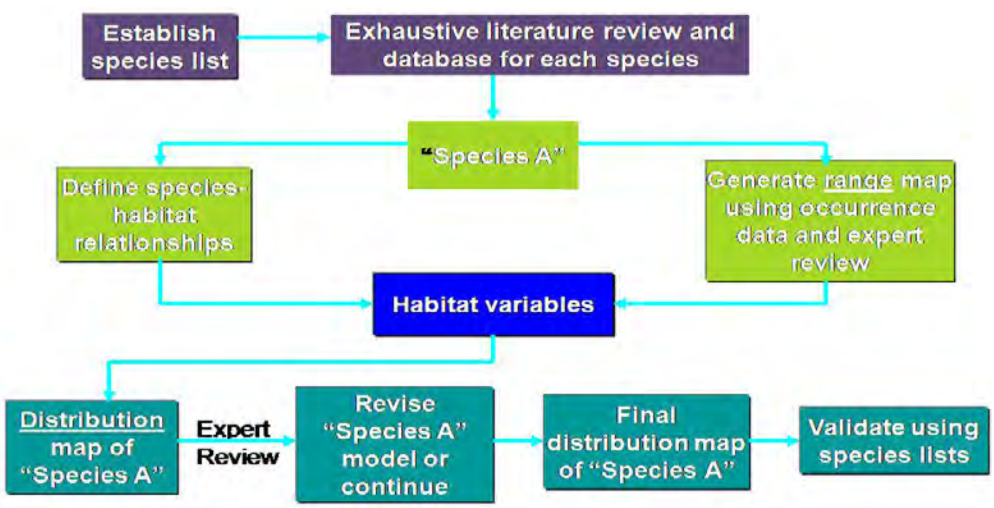



**Figure 2.** Steps involved with deductive modeling. These steps were taken to create species distribution maps for state-based GAP projects

Deductive models generally work well for well-known species that have clear, well-defined relationships with major environmental variables. They also are often the only option for modeling the distribution of very poorly-studied species for which there are few mapped occurrence records. However, deductive models typically over predict distributions when habitat associations or mapped land cover types are too general, when target species use environments that are difficult to define with satellite imagery, or when a species' distribution is strongly driven by interactions among environmental variables. If well mapped, land cover types are adequate surrogates for some complicated environmental patterns (Pressey 2004), but this is not true in all cases (Brooks et al. 2004).

In contrast to deductive modeling, inductive modeling is an approach whereby the multivariate environments at points of known occurrence are statistically summarized, and then extrapolated across the study area (Figure 3). Inductive modeling approaches (for example, Carpenter et al. 1993; Phillips et al. 2006; see Elith et al. 2006 for review) have gained in popularity for several reasons: resulting predictions are precise and repeatable; calculation methods are explicit and transparent; ease of use has increased as computer (particularly desktop GIS) technology has advanced; their primary inputs—georeferenced records of species occurrence and digital layers of environmental features—are increasingly available; and most inductive models can be easily re-run and improved with time and additional data (Elith et al. 2006).

Several algorithms have been developed to produce inductive models of species distributions, such as BioClim (Nix 1986), DOMAIN (Carpenter et al. 1993), GARP (Stockwell and Peters 1999), and MaxEnt (Phillips et al. 2004; Phillips et al. 2006). Recent reviews and comparisons of algorithms indicate that opportunistically-collected species occurrence data, if processed carefully, are appropriate for producing accurate distribution models, and that some algorithms (such as MaxEnt) produce generally more accurate and robust models than others (Elith et al. 2006; Hernandez et al. 2006; Phillips et al. 2006).

Most inductive modeling algorithms work best with abundant and well-distributed points of known species' presence, and suspected species' absence. The predictive power of an algorithm decreases as data quantity and quality decrease. Existing data may not meet the standards required by some algorithms, and additional sampling to boost data quantity and quality is often prohibitively expensive and time-consuming (Brooks et al. 2004).

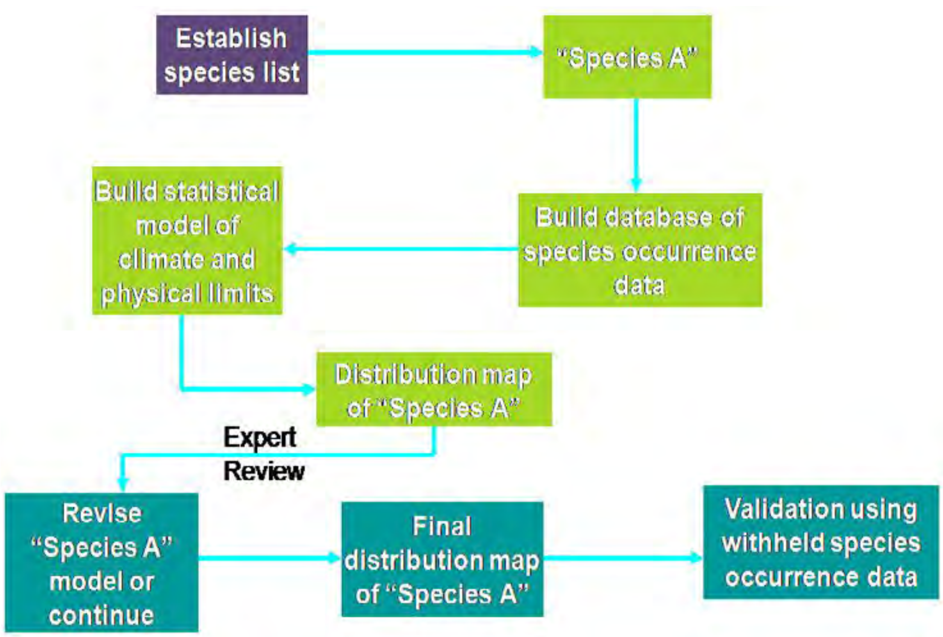



**Figure 3.** Steps involved with inductive modeling. These steps will be followed to create inductive species occurrence models for NWGAP.

Clearly, there are strengths and limitations to both deductive and inductive modeling approaches. For NWGAP we anticipate using purely deductive modeling for a few widespread species, species with coarse and well-established environmental relationships, and species whose available occurrence data are wholly inappropriate to inductive approaches. However, for most species we intend to combine the strengths of both modeling approaches to produce robust distribution models (Figure 4). This approach is designed to use the strengths of one approach to compensate for the weaknesses in the other (see discussion in Brooks et al. 2004).

Beauvais et al. (2003) describe the proposed combined modeling approach we intend to use for NWGAP (Figure 5). They collected species occurrence records for swift fox (*Vulpes velox*) in the five states of the U.S. Forest Service Rocky Mountain Region. These data were used as input to the DOMAIN (Carpenter et al. 1993) modeling algorithm to obtain a distribution map based on physical and climatic parameters (Figure 5). This map then was intersected with a deductive model of landcover types deemed suitable for occupation by swift fox. The intersection of the two maps encompassed 92 percent of the swift fox points in an independent validation data set, and was presented as the final predictive distribution map for the species in this region.

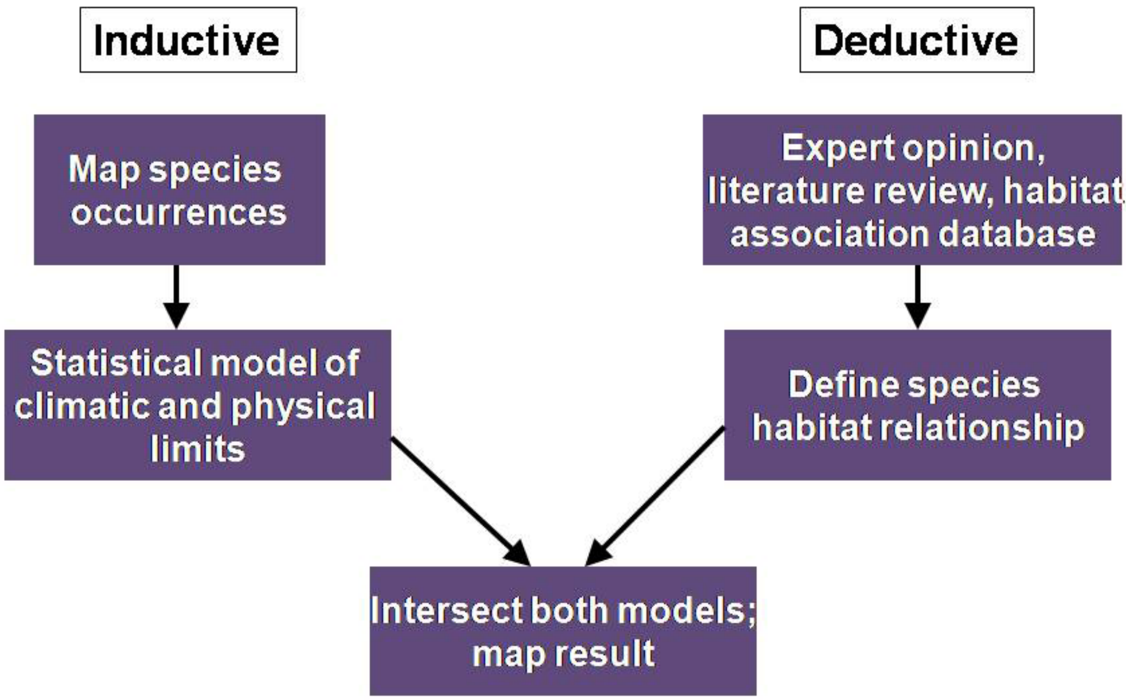



**Figure 4.** Our proposed method of combining the strengths of deductive and inductive modeling to construct better species occurrence models. This diagram describes the approach that will be used for creating species' distributions for NWGAP

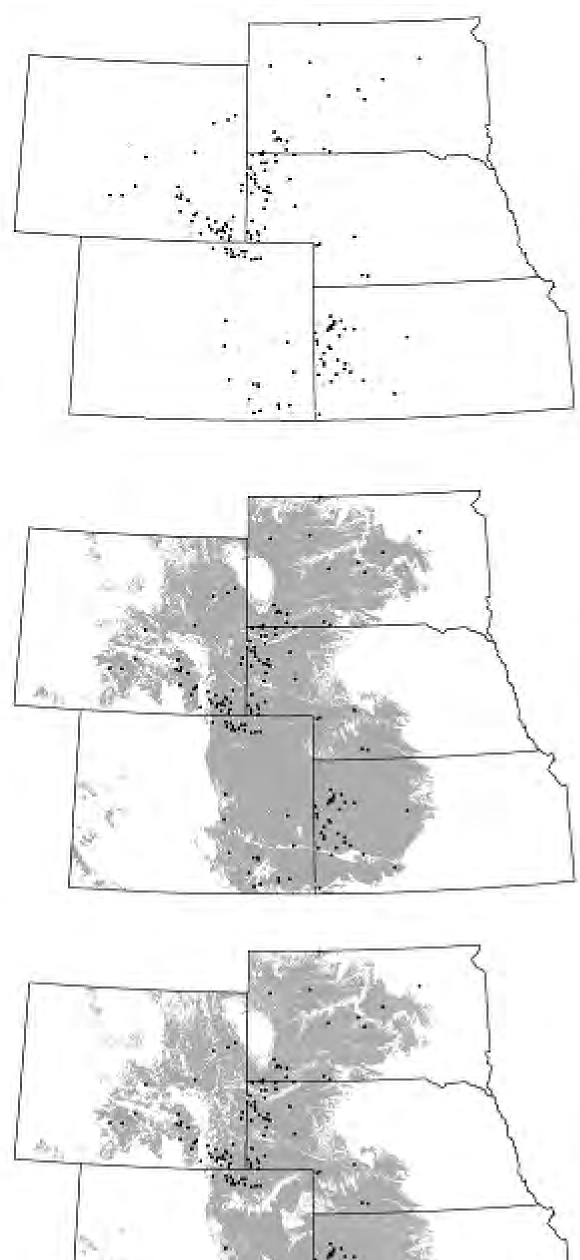


**Figure 5.** An example of combining inductive with deductive modeling using species occurrence and habitat association data for the swift fox (Vulpes velox; Beauvais et al. 2003). The top map shows the species occurrence data available in the five states of U.S. Forest Service (USFS) Region 2. Solid circles (75 percent of total) were used in the model and open circles (25 percent of total) were withheld and used for independent validation of the model. The middle map shows the results of the inductive model using the DOMAIN modeling algorithm with the gray areas indicating areas to be included in the model. The bottom map is the intersection of the two maps above resulting in a predicted distribution map for swift fox, which include 92 percent of the independent validation points (that is, open circles). Gray areas show (1) habitats associated with the species, as selected by Gap Analysis teams within each state, and (2) are within the suitable inductive model for the species. Note the areas that have been removed from the middle map to refine the predictive distribution in the bottom map.

## Summary

Our species modeling effort for NWGAP is collaborating with NHPs in the five Northwestern states. This collaboration will effectively and efficiently collect and process species occurrence data and provide access to vital biological expertise. The result will be a high quality and comprehensive compilation of species occurrence data. Furthermore, we are striving to create multiple maps (range, distribution and habitat quality), which represent multiple scales, for each terrestrial species occurring in the Northwest. Our intent is to make regional models more useful to local natural resource managers. Finally, in an effort to improve the accuracy of the final map for each species, we are combining the strengths of inductive and deductive modeling.

We have finalized the species list and assembled the species occurrence data in the Northwest. In 2007, we began modeling and within 3 years will have final species models and maps for use in the Northwest gap analysis as well as other conservation efforts.

## References Cited

Beauvais, G., and L. Master. 2005. Proposed procedure for modeling range, distribution, and habitat quality of vertebrates for Northwest GAP. Proposal submitted to National Gap Analysis Program.

Beauvais, G.P., R. Thurston, and D. Keinath. 2003. Predictive range maps for 15 species of management concern in the Rocky Mountain Region of the USDA Forest Service. Report prepared for the U.S. Geological Survey-National Gap Analysis Program by the Wyoming Natural Diversity Database-University of Wyoming, Laramie, Wyoming, USA.

Brooks, T., G.A.B. Da Fonseca, and A.S.L. Rodrigues. 2004. Species, data, and conservation planning. *Conservation Biology* 18:1682-1688.

Carpenter, G., A.N. Gillison, and J. Winter. 1993. DOMAIN: A flexible modeling procedure for mapping potential distributions of plants and animals. *Biodiversity and Conservation* 2:667-680.

Elith, J., C.H. Graham, R.P. Anderson, M. Dudík, S. Ferrier, A. Guisan, R.J. Hijmans, F. Huettmann, J.R. Leathwick, A. Lehmann, J. Li, L.G. Lohmann, B.A. Loiselle, G. Manion, C. Moritz, M. Nakamura, Y. Nakazawa, J.M. Overton, A.T. Peterson, S.J. Phillips, K. Richardson, R. Scachetti-Pereira, R.E. Schapire, J. Soberón, S. Williams, M.S. Wisz, and N. E. Zimmermann. 2006. Novel methods improve prediction of species' distributions from occurrence data. *Ecography* 29:129-151.

Hernandez, P., C.H. Graham, L.L. Master, and D.L. Albert. 2006. The effect of sample size and species characteristics on performance of different species distribution modeling methods. *Ecography* 29:773-785.

Merrill, E.H., T.W. Kohley, M.E. Herdendorf, W.A. Reiners, K.L. Driese, R.W. Marrs, and S.H. Anderson. 1996. *The Wyoming Gap Analysis Project Final Report*. Wyoming Cooperative Fish and Wildlife Research Unit, University of Wyoming, Laramie.

Morrison, M.L., and L.S. Hall. 2002. Standard terminology: Toward a common language to advance ecological understanding and application. Pages 43-52 in *Predicting Species Occurrences: Issues of accuracy and scale*. Editors: J.M. Scott, P.J. Heglund, and M.L. Morrison, et al., Island Press.

Nix, H.A. 1986. A biogeographic analysis of Australian elapid snakes. Pages 4-15 in *Atlas of Australian elapid snakes*. Series 8 Editor: R. Longmore. Commonwealth Scientific, Industrial, and Research Organization (CSIRO) Publishing, Collingwood, Victoria, Australia.

Phillips, S.J., R.P. Anderson, and R.E. Schapire. 2006. Maximum entropy modeling of species geographic distributions. *Ecological Modeling* 190:231–259.

Phillips, S.J., J. Dudík, and R.E. Schapire. 2004. A maximum entropy approach to species distribution modeling. *Proceedings of the 21st International Conference on Machine Learning*, Banff, Canada, 2004.

Pressey, R.L. 2004. Conservation planning and biodiversity; assembling the best data for the job. *Conservation Biology* 18:1677-1681.

Stockwell, D.R.B. and D.P. Peters. 1999. The GARP modeling system: problems and solutions to automated spatial prediction. *International Journal of Geographical Information Science* 13:143-158.

# Using GAP in Landbird Biological Objective-Setting: Process and Examples from Oak Habitats in the Pacific Northwest

Erin Stockenberg[1], Bob Altman[2], Michael Green[3], and John Alexander[4]

## Introduction

Landbird conservation has evolved considerably over the last 15 years under the Partners in Flight (PIF) initiative, and more recently under the coalition of the North American Bird Conservation Initiative (NABCI). In particular, Bird Conservation Regions (BCRs) have been identified as the desirable ecological units for bird conservation planning and implementation (North American Bird Conservation Initiative, 2000), and a conservation design process has been promulgated by PIF to support landbird biological objective-setting (Will et al. 2005). Additionally, Joint Venture partnerships (http://www.fws.gov/birdhabitat/JointVentures/DefineJV.shtm) have been identified as an important implementation delivery mechanism for the conservation of all bird species and their habitats. In order to track bird conservation progress, Joint Venture partnerships are conducting analyses and designing landscapes with spatially-explicit habitat objectives that are directly linked to bird population objectives. Increasingly, population targets are being recommended as the metric for bird conservation, and the PIF Continental Plan (Rich et al. 2004) initiated this discussion for landbirds by presenting population objectives at the continental scale.

One essential component of the analytical process for landbird conservation design and biological objective-setting is the use of geospatial data to characterize the extent, type, and condition of the land cover types used by the bird species of interest (Will et al. 2005). These data, in conjunction with other geospatial data (for example, land ownership) and data on the degree of occurrence of birds in the habitat types (bird density estimates), are being used to estimate current bird population size and model future habitat scenarios to set habitat and population objectives.

The U.S. Geological Survey's Gap Analysis Program (GAP) data can be used to provide the essential land cover geospatial component of the landbird conservation design process (for example, Drew et al. 2006). Herein, we describe our process for setting regional biological objectives, and the role of GAP data in that process for oak habitats and associated bird species in the Northern Pacific Rainforest Bird Conservation Region (BCR 5; Figure 1). We also present some preliminary examples of outputs of the process for one species, Chipping Sparrow (*Spizella passerina*) from the seven ecoregions within BCR 5.

## Project Area

The Northern Pacific Rainforest Bird Conservation Region is a relatively narrow strip of coastal landscape less than 150 miles wide that stretches from the western Gulf of Alaska south through western British Columbia, Oregon, Washington, and northwestern California. Oak habitats in BCR 5 occur as disjunct patches primarily in interior valleys and at lower elevations south of southwestern Vancouver Island, British Columbia. However, in southwestern Oregon and northwestern California, oak habitats also occur in montane forests as oak-dominant stands or often mixed with other hardwood or conifer trees. To facilitate the practical applications of our analyses, we subdivided the project area into seven ecological units that also mirror the relatively disjunct distribution of oak habitats (Figure 2).

[1] U.S. Fish and Wildlife Service, Realty and Refuge Information, Portland, Oregon.

[2] American Bird Conservancy, Corvallis, Oregon.

[3] U.S. Fish and Wildlife Service, Division of Migratory Birds and Habitats, Portland, Oregon.

[4] Klamath Bird Observatory, Ashland, Oregon.

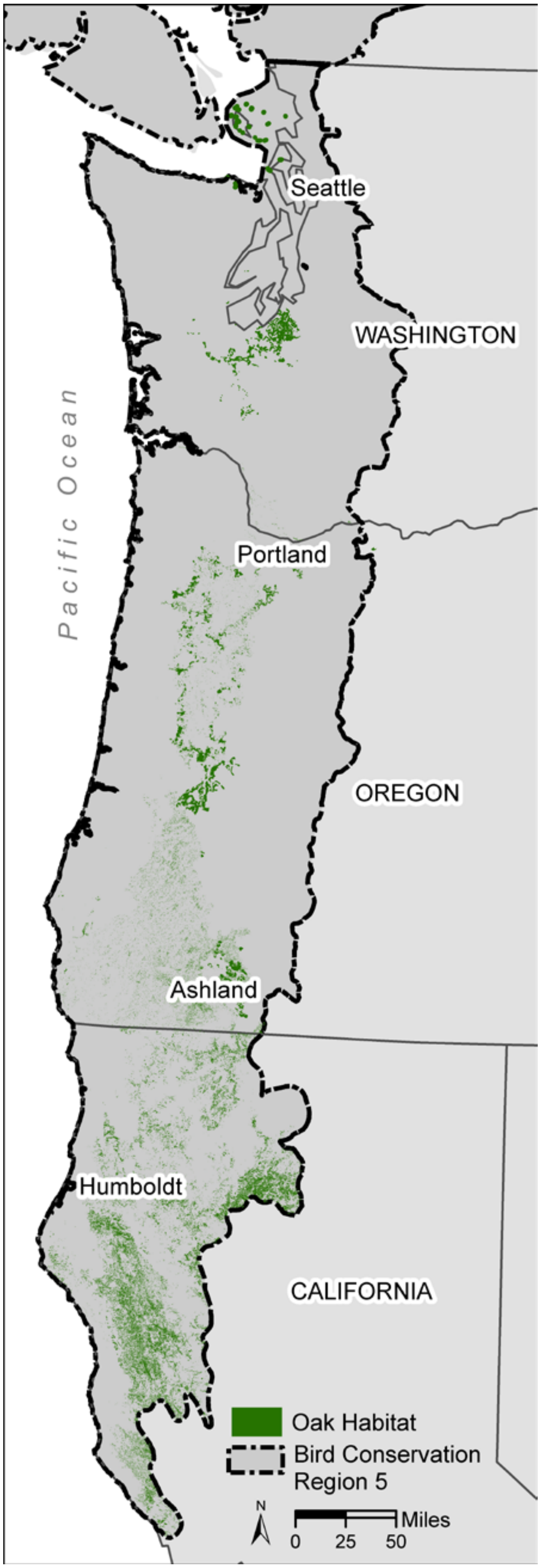



**Figure 1.** Oak habitat within Northern Pacific Rainforest Bird Conservation Region (BCR 5).

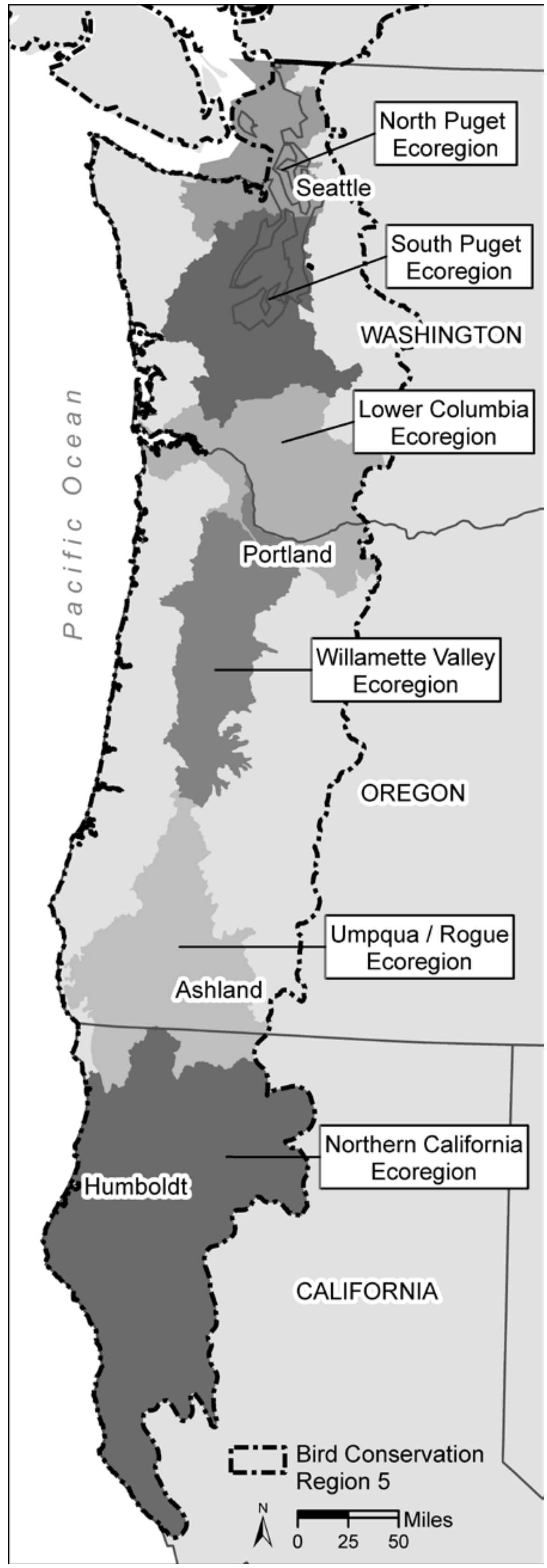



**Figure 2.** Project ecoregions within Northern Pacific Rainforest Bird Conservation Region (BCR 5).

## Conceptual Approach

We modeled breeding bird-habitat relationships and conducted geospatial analyses to estimate current habitat availability and bird populations, and established 30-year bird population and habitat objectives at several scales (for example, BCR, ecoregions, sites) by projecting future land use/management for a suite of focal species that define the quantity and quality of the range of desired habitat conditions for birds in oak habitats. This approach builds on PIF bird conservation plans for Washington, Oregon, and California by using focal species to emphasize conservation of all the important components of the habitat type (that is, ecosystem conservation), and by focusing attention on habitat features and conditions most important for birds in a functioning ecosystem. This ecosystem approach also supports the habitat and species prioritization efforts in numerous other plans and strategies of partners in bird conservation such as State Wildlife Action Plans, The Nature Conservancy Ecoregional Assessments, and U.S. Fish and Wildlife Service (USFWS) National Wildlife Refuge System (NWRS) Comprehensive Conservation Plans.

A key conceptual component of our approach is the premise that regional biological objectives (habitat objectives and population objectives) should be derived based on regional habitat capacity as determined by an analysis process of current and future projected land use and conditions. Thus, our population objectives are an output of the regional habitat capacity analysis process, and not an input into the analysis that has been stepped-down from continental objectives. Our analysis initially produces a habitat objective based on the difference between current and future projected habitat. The habitat objective is translated into a regional population objective, which is the difference between the current population estimate and the future population estimate derived from the projected future habitat capacity.

## Process and Preliminary Example Results

1. Access, review, and integrate appropriate geospatial data for the study area, especially bird distribution, ecoregions, land cover/habitat types, land conditions, and land ownership.

   In the Washington part of BCR 5, we used oak habitat data layers from the Northwest Gap Analysis Project (NWGAP; http://www.gap.uidaho.edu/northwest/home.htm) and Washington Department of Natural Resources (Washington Department of Natural Resources [WDNR]; Chappell et al. 2003). In the Oregon part of BCR 5, we used the Ecological Systems layer produced by the Oregon Natural Heritage Program (ONHP) (Kagan 2005) in conjunction with the Northwest Habitat Institute (NHI) Draft Willamette Valley Oak and Pine Habitat Conservation Project (Northwest Habitat Inisitute 2007). NWGAP and Ecological Systems are modeled landcover maps developed using remotely sensed imagery. They included only one oak habitat type, North Pacific Oak Woodland. The WDNR and the NHI oak layers were developed using aerial photography interpretation and field verification, and included numerous oak types: (for example, oak-dominant forest or woodland canopy, oak-conifer forest or woodland canopy, scattered oak canopy, urban oak canopy), as well as information on canopy cover and tree size. A union of the two layers (one union for Washington and one union for Oregon) results in reduced likelihood of errors of omission, a greater level of confidence in the use of the modeled land cover layers, and a more complete layer that incorporated the most detailed information from both layers. When the layers were combined there was often an overall similarity but never an exact match between the spatial distributions of oak woodlands. For the California part of BCR 5, we used the oak habitat layer from the California Department of Forestry and Fire Protection (FRAP) program. This layer was combined with existing vegetation coverages that were produced by the USDA Forest Service Remote Sensing Lab (Region 5) using the CALVEG classification system.

   Ecoregions were used to provide finer-scale analyses of the biological objective-setting process based on similarities in physiography and land use/management. In Washington, ecoregions were delineated using Hydrologic Unit Code (HUC) watersheds merged to create the North Puget, South Puget, and Lower Columbia ecoregions. In Oregon, ecoregions were based on the Level IV ecoregion designations (Omernik 1987). In California, ecoregions were based on the hydrologic unit boundaries from California Interagency Watershed Map of 1999.

   Land ownership was gathered from a variety of sources and processed for each state. The scale of ownership (for example, private vs. public, types of public ownership, site-level ownership) was variable, but we always used the finest scale available. In Washington, we used a layer created by CommEnSpace which was based in part on the Protected Areas Database

Version 3 (Conservation Biology Institute 2005) and the Washington Department of Natural Resource's Non-Department of Natural Resources Major Public Lands (Washington Department of Natural Resources 2005). In Oregon, we used a combination of layers including; Oregon Department of Forestry's Public Ownership (Oregon Department of Forestry 2005), Oregon Department of Fish and Wildlife's Wildlife Refuge Boundaries (Oregon Department of Fish and Wildlife 2006), and County tax lot data. In California, we used Public, Conservation and Trust Lands Version 05_1 (California Resource Agency 2007). Data were combined using an overlay, boundaries were corrected to remove slivers and gaps, and attributes were transferred to the appropriate ownership field. Several scales of ownership were tracked including; public vs. private ownership, government agency vs. NGO vs. private ownership or management, and the actual site name.

2. Select a suite of focal bird species that represent the range of desired habitat conditions for birds in the habitat.

   The assumption inherent to this approach is that conservation directed towards the collective needs of a suite of focal bird species that represent the range of desired habitat conditions for birds should also address the habitat needs of most, if not all, of the other bird species occurring in that habitat type (Lambeck 1997). The use of a suite of focal species is an efficient and comprehensive way to address ecosystem conservation, and it also provides an established framework for addressing current and future priority species (Franklin 1993; Hutto 1998).

   We reviewed the scientific literature on bird-habitat relationships in oak habitats to determine the important habitat features or conditions most associated with bird species habitat selection or use in the ecologically desired conditions for the habitat type. We used this information to determine the range of desired habitat conditions for birds in oak habitats and identified 20 focal species representative of those conditions (Table 1). Focal species were selected from a review of the bird-habitat relationship literature for oak habitats and the Oregon-Washington and California Partners in Flight Bird Conservation Plans for oak habitats (Altman 2000; CalPIF 2002, respectively) based on the following criteria:

   - Regularly occur as breeding species throughout the geographic area under consideration,
   - Are strongly associated with the habitat and the habitat is a primary habitat type for the species, and they reach some of their highest breeding densities in this habitat type,
   - Are strongly associated with an important habitat attribute or condition within the habitat such that they would demonstrate responses to management or restoration targeted at the habitat attribute or condition, and
   - Are readily monitored using standard techniques to be able to track progress towards objectives at multiple scales.

3. Develop a biological parameters database for each focal bird species that includes the type (coarse scale) and condition (fine scale) of suitable habitat for each species, and the distribution of the species across the landscape (habitat-specific and condition-specific density estimates).

   We reviewed the scientific literature to determine focal bird species habitat relationships and density estimates for each suitable habitat type and condition. We used data that were as local as possible in establishing density estimates. Site-specific density estimates were used where available; otherwise ecoregional mean density estimates were applied to each site (see Table 2 for an example using the Chipping Sparrow).

4. Conduct geospatial analyses to characterize current habitat availability for each focal bird species based on integration of habitat classifications in GIS layers (1) with suitable habitat parameters (3).

   Area of habitat availability for each focal species was calculated by adding the area of all polygons in the GIS layer that were considered suitable habitat (Table 3).

5. Estimate current population size of each focal bird species at ecoregional scales by multiplying habitat-specific mean bird density estimates (3) and area of current habitat availability (4) (Table 4).

   The population estimate is not a direct calculation of total oak habitat times ecoregional mean density for several reasons: most ecoregions have several types of oak habitats, most ecoregions have some sites where site-specific densities are used rather than ecoregional mean densities, and a pair correction factor was used to account for undetected females in the population that are not usually represented in the bird density data (mostly only singing males are recorded).

**Table 1.** Focal species and associated habitat conditions by ecoregions for oak habitats in the Northern Pacific Rainforest Bird Conservation Region.

[**Ecoregions:** NPS, North Puget Sound; SPS, South Puget Sound; LCR, Lower Columbia River; WV, Willamette Valley; UV, Umpqua Valley; RV, Rogue Valley; NWC, Northwestern California. Shading indicates species does not occur or only occurs sparingly as a breeding species in this ecoregion; X indicates focal species in each ecoregion that will be tracked at the regional level and are suggested as the focal species to be tracked at local/site levels, although other focal species can be used if more appropriate (for example, regional focal species not present or minimally present at site)]

| Habitat condition or feature (Focal Species Habitat Association) | Focal species | Ecoregion | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | NPS | SPS | LCR | WV | UV | RV | NWC |
| Large trees with large cavities (edges; interior small patches) | Acorn Woodpecker | | | | | X | | X |
| Large trees with large cavities (edges; small and large patches) | Ash-throated Flycatcher | | | | | | X | |
| Large trees with large cavities (edges and interior; small and large patches) | Downy Woodpecker | | X | X | X | | | |
| Large or small trees with small cavities (savannah trees) | Western Bluebird | | | | | | | X |
| Large or small trees with small cavities (edges; interior small patches) | White-breasted Nuthatch | | | | X | | | |
| Large or small trees with small cavities (edges and interior; small and large patches) | Black-capped Chickadee | | X | | | X | | |
| Large or small trees with small cavities (edges and interior; small and large patches) | Oak Titmouse | | | | | | X | |
| Large or small trees with small cavities (edges; interior small patches) | House Wren | X | | X | | | | |
| Mature overstory foliage/open canopy (edges; small and large patches) | Western Wood-pewee | | X | X | X | | | |
| Mature overstory foliage/closed canopy (interior large patches) | Black-throated Gray Warbler | X | | | | | | |
| Mature overstory foliage/open & closed canopy (edges; interior small patches) | Purple Finch | | | | | X | X | |
| Mature overstory foliage/open & closed canopy (edges and interior) | Cassin's Vireo | | | | | | | X |
| Mature or Young overstory/closed canopy (edges and interior; small and large patches) | Blue-gray Gnatcatcher | | | | | | X | |
| Mature or Young overstory/open canopy (edges; interior small patches) | Lesser Goldfinch | | | | | X | | |
| Mature midstory; Young overstory (edges; interior small patches) | Bushtit | | | X | | | | |
| Mature subcanopy; Young overstory (closed) (interior; small and large patches) | Hutton's Vireo | | | | X | | | |
| Mature understory/ground; Young overstory/ground (open-closed) (edges: interior small patches) | Chipping Sparrow | X | X | X | X | | | |
| Mature understory/ground; Young overstory/ground (open canopy) (edges: scattered shrub patches) | Lazuli Bunting | | | | | X | | |
| Mature understory/ground; Young overstory/ground (open canopy) (edges: dense shrub patches) | California Towhee | | | | | | X | |
| All layers: canopy/subcanopy/ground (edges and small patches) | Western Scrub Jay | | | X | X | X | X | X |

**Table 2.** Density estimates (Task 3) for Chipping Sparrow in oak habitats in seven ecoregions in the Northern Pacific Rainforest Bird Conservation Region (BCR 5).

| Ecoregion | Ecoregional mean densities (birds/hectares) |
|---|---|
| North Puget Sound | 0.30 (extrapolated from South Puget Sound) |
| South Puget Sound | 0.30 (n=48) |
| Lower Columbia | 0.05 (n=5) |
| Willamette Valley | 0.09 (n=25) |
| Umpqua Basin | 0.27 (valley); 0.05 (montane) (both extrapolated from Rogue Basin) |
| Rogue Basin | 0.27 (valley) (n=4); 0.05 (montane) (n=12) |
| Northwestern California | 0–0.30 (n=7) (varies by oak type) |

**Table 3.** Oak habitat (Task 4) delineated in geospatial layers used in biological objective-setting in the Northern Pacific Rainforest Bird Conservation Region (BCR 5).

[ha, hectares]

| Ecoregions | Washington | | Overlap between two layers (ha) | Oregon | | California |
|---|---|---|---|---|---|---|
| | WDNR (ha) | NWGAP (ha) | | NHI (ha) | ONHP Ecol. Systems (ha) | FRAP (ha) |
| North Puget Sound | 102 | 200 | 57 (29-56) | | | |
| South Puget Sound | 6,736 | 5,873 | 3,818 (57-65) | | | |
| Lower Columbia | 532 | 439 | 329 (38-43) | | | |
| Willamette Valley | | | 7,513 (22-41) | 34,220 | 18,297 | |
| Umpqua Basin | | | | | 19,273 | |
| Rogue Basin | | | | | 79,376 | |
| Northwestern California | | | | | | 937,642 |

**Table 4.** Current (Task 5) and future (Task 9) population estimates and population objectives (Task 11) for Chipping Sparrow in oak habitats in seven ecoregions in the Northern Pacific Rainforest Bird Conservation Region (BCR 5).

| Ecoregion | Current population estimate | 30-year future population projection | Ecoregional population objective |
|---|---|---|---|
| North Puget Sound | 82 | 118 | Increase population by 45 percent |
| South Puget Sound | 2,859 | 3,212 | Increase population by 12 percent |
| Lower Columbia | 123 | 104 | Maintain population (lose 15 percent) |
| Willamette Valley | 4,145 | 5,210 | Increase population by 20 percent |
| Umpqua Basin | 10,039 | 9,185 | Maintain population (lose 9 percent) |
| Rogue Basin | 8,437 | 8,876 | Increase population by 5 percent |
| Northwestern California | 159,716 | 155,315 | Maintain population (lose 3 percent) |
| Totals | 185,401 | 182,020 | Maintain population (lose 2 percent) |

6. Coordinate with principal conservation partners to discuss and quantify projected land use or land management activities (for example, development, resource extraction, habitat creation, habitat restoration, habitat enhancement, natural succession) that would affect land use and habitat relevant to birds, and create quantitative databases that reflect these projections.

   We used expert knowledge through consultation with land managers/ecologists/biologists to quantify projected future land use/management activities (Table 5). We assumed relative stability of oak habitats and potentially favorable management on most lands owned or managed by conservation organizations (for example, The Nature Conservancy) or public agencies (for example, State Parks, National Wildlife Refuges, National Forests). We assumed some degree of habitat loss with limited conservation management on private lands.

**Table 5.** Examples of future projections of habitat loss and change (Task 6) in oak habitats in the South Puget Sound ecoregion within the Northern Pacific Rainforest Bird Conservation Region (BCR 5).

[**Habitat:** Development, loss to roads, buildings etc.; Degradation, conifer-dominant to lost; Restoration, change from oak-conifer to oak-dominant; Succession, change from oak-dominant to oak-conifer]

| Site | Habitat loss (percent) | | Habitat change (percent) | |
|---|---|---|---|---|
| | Development | Degradation | Restoration | Succession |
| Fort Lewis | 1 | 5 | 30 | 1 |
| Scatter Creek Wildlife Area | 0 | 10 | 50 | 10 |
| Shafer State Park | 0 | 5 | 5 | 0 |
| Parkway/Spanaway Private | 5 | 10 | 5 | 5 |

7. Access, review, and integrate available geospatial data that project future changes (for example, population growth, land use changes) that would affect land use and habitat relevant to birds, and create quantitative databases and geospatial layers (if possible) that reflect these projections.

   We used a "Futures" geospatial analyses that predicted landcover changes from 2000-2002 The Futures analysis is based on an overlay of the National Land Cover Database (NLCD) (Homer et al. 2004) classes with visualizations of the future landscape for Pierce County and Thurston County, Washington (two counties within the South Puget Sound) (CommEnSpace. 2005). We then overlaid the "Futures" layers on the 2001 NLCD and conducted a change detection which determined that 3 percent of the oak habitat is projected to be lost during the 20-year period. This is a 11 percent loss over the 30-year period of our objective-setting. We used this amount for the South Puget Sound analyses, but tempered it to 10 percent for the North Puget Sound where population growth and associated loss of habitat to development is expected to be less. The CommEnSpace analysis was used because of its readiness and consistency in classes from ecoregion to ecoregion. Although the NLCD has relatively coarse classes compared to GAP data, it provided a good measure for potential losses and gains for classes that include oak habitat.

8. Apply data and geospatial analyses from projected land management (6) and projected land-use or socioeconomic changes (7) to modify current habitat availability (4) and calculate future habitat availability for each focal species.

9. Estimate future populations of each focal bird species at ecoregional scales by multiplying habitat-specific or habitat condition-specific bird density estimates (3) and area of future habitat availability (8) (Table 4).

10. Establish preliminary habitat objectives for each habitat or habitat condition at ecoregional scales by subtracting current habitat (4) from future habitat (8) and converting the raw number to a percent difference from current habitat (for example, change habitat in a prescribed manner by X percent).

    Habitat objectives are considered preliminary because they will need to be vetted with habitat objectives from other adjacent and ecologically conflicting habitats (for example, grasslands, conifer forests) in an optimization process to determine final habitat objectives.

11. Establish preliminary population objectives for each focal bird species at ecoregional scales by subtracting current population estimate (5) from future population estimate (9) and converting the raw number to a percent difference from current population estimate (for example, increase population by X percent) (Table 4).

    Population objectives are 30-year objectives to be consistent with the time frame used in the PIF Continental Plan (Rich et al. 2004).

## Roles and Challenges of Gap Data

There is great value in using GAP data in these types of analyses because it provides a seamless, single geospatial layer and classification scheme for the entire project area. Furthermore, GAP data and classifications are most suited for use at regional scales. Thus, our analyses and outputs using NWGAP data at the level of BCR 5 or ecoregions within BCR 5 should provide reasonable biological objectives at those scales. However, most land managers need objectives at the smaller scales in which they work (for example, sites such as wildlife refuges or management areas). To accurately model at smaller scales, GAP data should be supplemented by other data sources that include measures of habitat quality or condition. The finer-scale accuracy and lack of habitat quality or condition in GAP data is problematic when trying to set local habitat and (or) population objectives that are dependent on the site-specific habitat conditions. In our analyses, we were able to supplement NWGAP data with WDNR oak layer in Washington and NHI oak layer in part of Oregon, both of which provide finer-scale information on habitat type or condition.

For this project, all the geospatial data that was available for oak habitat, including NWGAP, were of varying degrees of detail and accuracy. Both modeled landcover maps (raster) and field verified and mapped layers (vector) were used. When these layers were compared (raster vs. vector) the obvious and expected differences became apparent. This is especially true of ecosystems like oak habitats that are not uniform in their spectral signature because they contain a mosaic of several oak types. The modeled landcover layers (NWGAP and Ecological Systems), although more complete in terms of mapped geographic extent, routinely misclassified oak habitats at the extreme (oak savannah where scattered oaks occur in grasslands, and oak woodlands with approximately 50 percent conifer overstory) based on our field checks for a related project (see Future Work). The field-verified landcover layers (WDNR and NHI), although potentially inconsistent in degree of coverage due to accessibility issues, provided greater accuracy and added measures of habitat condition. The combination of the two layers results in reduced likelihood of errors of omission, and also provides opportunities for field evaluation of concurrence/disagreement and development of correction factors.

NWGAP data will be more widely available for this project in the near future. Mapping Zones 2 and 7 include the Willamette Valley and Klamath Basin and will be available in autumn 2007. Ecological system mapping in California will be starting in 2007. These layers will undoubtedly enhance our ability to model and revise estimates because the data will be standardized across the region and will reflect current conditions, although they will still lack the fine scale data such as habitat quality (age, structure, canopy) that are key components to site-specific modeling.

## Future Work

We are currently completing the analyses for all 20 focal species. We also recently completed bird surveys (that is, spot-mapping to determine complete population counts) at 21 oak sites within BCR 5 to calibrate the population estimation process of our model and compare our predicted populations based on the modeling and analysis process with those derived from the bird surveys. As part of this work, we also will be assessing the accuracy of NWGAP oak habitat mapping at each site, and examining how that mapping affects our population estimates and biological objectives across BCR 5. Ultimately, we will be able to compare the population estimates generated from our regional habitat-based approach with those stepped-down from the continental Breeding Bird Survey analysis as described in the PIF Continental Plan (Rich et. al. 2004).

## Acknowledgments

The U.S. Fish and Wildlife Service, National Wildlife Refuge System's Division of Planning and the Division of Migratory Birds and Habitat, Portland, OR, the U.S. Geological Survey's Gap Analysis Program, the Pacific Coast Joint Venture, and the Neotropical Migratory Bird Conservation Act supported this work. We thank M. Stevenson of CommEnSpace and D. Stahlberg of PRBO Conservation Science for conducting the geospatial data analysis for the North Puget Sound and Northwestern California, respectively.

## References Cited

Altman, B. 2000. *Conservation strategy for landbirds in the lowlands and valleys of western Oregon and Washington.* Version 1.0. American Bird Conservancy and Oregon-Washington Partners in Flight. http://www.orwapif.org

California Department of Forestry and Fire Protection (FRAP). 2002. *Multi-source Land Cover Data (v02_1)*, Map Supp. http://frap.cdf.ca.gov/projects/frap_veg/index.asp. Sacramento, CA.

California Interagency Watershed Mapping Committee. 1999. *California Interagency Watershed Map of 1999* (CalWater 2.2.1), Map Supp. Sacramento, CA. http://www.ca.nrcs.usda.gov/features/calwater/#Data

California Resources Agency, Data developed under contract by VESTRA Resources, Inc. 2007. *Public, Conservation and Trust Lands*, *v05_2*, Map Supp. Sacramento, CA. http://gis.ca.gov/meta.epl?oid=31122

CalPIF (California Partners in Flight). 2002. *The oak woodland bird conservation plan: a strategy for protecting and managing oak woodland habitats and associated birds in California* (S. Zack, lead author). Version 2.0. Point Reyes Bird Observatory, Stinson Beach, CA. http://www.prbo.org/calpif/plans.html

Chappell, C.B., M.S. Gee, and B. Stephens. 2003. *A geographic information system map of existing grasslands and oak woodlands in the Puget Lowland and Willamette Valley ecoregions, Washington*, Map Supp. Washington Natural Heritage Program and Washington Department of Natural Resources. Olympia, WA.

CommEnSpace. 2005. *Pierce County visualizations based on NLCD data for 1992 & 2001*. http://www.commenspace.org/services/initiatives/pierce_vis.html

Conservation Biology Institute. 2005. *Protected Areas Database Version 3*. Corvalis, OR. http://www.consbio.org

Drew, A., A.J. McKerrow, and S. Earsom. 2006. Stepping down regional habitat and population objectives to individual national wildlife refuges: a pilot project in the Roanoke-Tar-Neuse-Cape Fear (RTNCF) ecosystem. *Gap Analysis Bulletin* 13: 8-9.

Franklin, J.F. 1993. Preserving biodiversity: species, ecosystems, or landscapes? *Ecological Applications* 3(2):202-205.

Homer, C., C. Huang, L. Yang, B. Wylie, and M. Coan. 2004. Development of a 2001 national land cover database for the United States. *Photogrammetric Engineering and Remote Sensing* 70 (7):829-840. http://www.mrlc.gov/pdfs/July_PERS.pdf

Hutto, R. 1998. Using landbirds as an indicator species group. *Avian Conservation: Research & Management*. Island Press, Covelo, CA. pgs. 75-92.

Kagan, J. 2005. *Ecological Systems Map Supp*. Oregon Natural Heritage Program. Portland, OR.

Lambeck, R.J. 1997. Focal species: a multi-species umbrella for nature conservation. *Conservation Biology* 11(4):849-856.

North American Bird Conservation Initiative. 2000. *North American Bird Conservation Initiative: Bird Conservation Region descriptions*. U.S. Fish and Wildlife Service, Washington, D.C.

Northwest Habitat Institute. 2007. *Willamette Valley oak and pine habitat conservation project*, Map Supp. Prepared for National Fish and Wildlife Foundation, Bureau of Land Management, and U. S. Forest Service. Corvallis, OR http://www.nhi.org

Omernik, J.M., 1987, *Ecoregions of the conterminous United States (map supplement): Annals of the Association of American Geographers*, v. 77, no. 1, p. 118-125, scale 1:7,500,000. Oregon Department of Forestry, 2005. Public Ownership Map Supp. http://www.oregon.gov/ODF/GIS/gis_home.shtml

Oregon Department of Fish and Wildlife. 2006. Draft Wildlife Management Areas. Map Supp.

Oregon Department of Forestry. 2005. Public Ownership. Oregon Department of Forestry GIS. Salem, OR. http://www.oregon.gov/ODF/GIS/gis_home.shtml

Rich, T.D., C.J. Beardmore, H. Berlanga, P.J. Blancher, M.S.W. Bradstreet, G.S. Butcher, D.W. Demarest, E.H. Dunn, W.C. Hunter, E.E. Iñigo-Elias, J.A. Kennedy, A.M. Martell, A.O. Panjabi, D.N. Pashley, K.V. Rosenberg, C.M. Rustay, J.S. Wendt, and T.C. Will. 2004. *Partners in Flight North American Landbird Conservation Plan*. Ithaca, NY, Cornell Lab of Ornithology, http://www.partnersinflight.org/cont_plan/

Washington Department of Natural Resources. 2005. *Washington State Non-Department of Natural Resources Major Public Lands*, Map Supp. Olympia, WA. http://www3.wadnr.gov/dnrapp6/dataweb/dmmatrix.html

Will, T.C., J.M. Ruth, K.V. Rosenberg, D. Krueper, D. Hahn, J. Fitzgerald, R. Dettmers, and C.J. Beardmore. 2005. The five elements process: designing optimal landscapes to meet bird conservation objectives. *Partners in Flight Technical Series*, No. 1. http://www.partnersinflight.org/pubs/ts/01-FiveElements.pdf

APPLICATIONS

# Use of Explicit Decision Rules for the Identification of Conservation Priorities in Eastern San Diego County

Adam Wagschal[1] and Melanie Ann Casey[1]

## Introduction

The County of San Diego is currently developing a Habitat Conservation Plan (East County Multiple Species Conservation Plan (County of San Diego 2007)) for lands in eastern San Diego County, California. As part of the planning process, vegetation communities[2] (classified by Holland [1986] as modified by Oberbauer [1996]) have been prioritized for conservation actions on privately owned lands. The purpose of this article is to describe the process that was used to assign each vegetation community a conservation priority level. Prioritization was based upon the application of explicit decision rules to the following quantitative criteria: (1) the current conservation status of each vegetation community; (2) the proportion of each vegetation community that occurs on privately owned land; and (3) the rarity of each vegetation community. Qualitative factors were also considered. The process resulted in each vegetation community being assigned as a "Low", "Medium", or "High" conservation priority. Use of explicit decision rules ensured that with each priority level assignment, a consistent standard was applied. Additionally, the decision rules allowed for a transparent decision making process that facilitated critical review.

This analysis involved an assessment of each vegetation community's conservation status, and subsequent prioritization of each vegetation community for conservation actions on privately owned lands. The methods used to assess each vegetation community's conservation status were similar to Gap Analysis methods (Crist 2000); however, more specific assumptions regarding future land conservation were considered. New methods were developed to prioritize vegetation communities for conservation actions on privately owned lands. The general prioritization methods that were developed may be useful for other efforts.

[1] Department of Planning and Land Use, County of San Diego, San Diego, CA.

[2] Vegetation communities in the Planning Area were mapped in 1995. As urban and agricultural development have occurred the vegetation data has been updated. The minimum mapping unit of the vegetation data is 0.1 acres.

## The Planning Area

The Planning Area consists of approximately 1.6 million acres in eastern San Diego County. This area is owned by multiple entities including the County of San Diego, the State of California, the Federal government and private landowners. Although the entire Planning Area is being considered in the planning process, the focus of the East County Multiple Species Conservation Plan is to develop conservation strategies for privately owned lands. Privately owned lands account for approximately 26 percent (418,930 acres) of the Planning Area. The Planning Area is ecologically diverse, and includes both montane and desert ecosystems.

## Conservation Status Assessment

The existing conservation status of each vegetation community was one of three quantitative criteria considered during prioritization of vegetation communities. The assessment of each vegetation community's conservation status was based on the potential of current and proposed land management activities to maintain the ecological value of each vegetation community.

### Assignment of Resource Management Status Categories

Spatial data depicting land management units (areas of land with different management goals) was received from each major landowner in the Planning Area. Subsequently, each land management unit was assigned to one of four Resource Management Status (RMS) Categories, as depicted in Figure 1. The RMS Categories reflect the relative potential of current and proposed management to sustain the ecological values of land. To define the RMS Categories, the criteria described by Crist (2000) were modified. Modifications to Crist's (2000) criteria were useful for the following reasons:

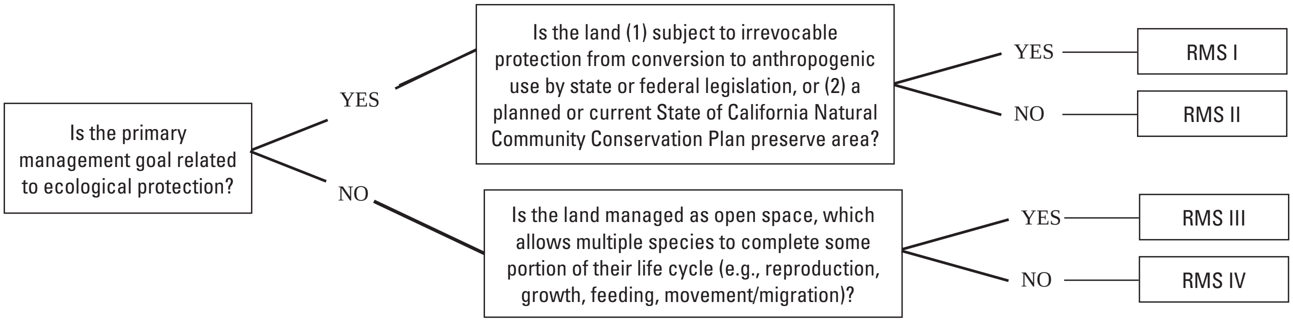



**Figure 1.** The process for determining the Resource Management Status (RMS) Category of individual land management units (modified from Crist (2000)).

1. In the Planning Area, there is substantial land that is managed for ecological resources, but does not have permanent protection from natural land conversion. For example, land owned by a non-profit organization, which is managed for ecological resources, but does not have any formal protection such as a conservation easement. Future protection of this land is likely. However, it is not appropriate to place this land in the same category as lands that are currently protected. Hence, unlike Crist's (2000) criteria, RMS Category I and RMS Category II allow for the differentiation between (1) lands that are managed for ecological resources and are permanently protected (RMS Category I); and (2) lands that are managed for ecological resources, but are not currently protected (RMS Category II).

2. In the Planning Area, there are several planned State of California Natural Community Conservation Plan preserves. There are existing obstacles to establishing these preserves. However, within the context of this conservation planning effort, it was more appropriate to assume that these preserves will be established rather than assume that the efforts to establish these preserves will fail. Hence, the criteria that were developed allow for these planned preserves to be placed in RMS Category.

3. As indicated above, this analysis was based on specific assumptions regarding future land conservation actions. These assumptions were appropriate because the researchers conducting this analysis are closely involved in local land use decisions and hence are capable of making reasonable assumptions regarding future land conservation. For Gap Analysis conducted at larger spatial scales, researchers are less likely to have close involvement in local land use decisions and similar assumptions may not be appropriate.

## Analysis of Vegetation Communities by Ecoregion

The County of San Diego has been divided into 16 ecoregions, which are defined by unique climates and topography. Within each ecoregion, an individual vegetation community may have unique ecological functions. Hence, it is important to ensure that each vegetation community is adequately conserved within each ecoregion. Additionally, conserving each vegetation community within each ecoregion helps ensure that the general distribution of each vegetation community will be maintained throughout the Planning Area. Therefore, the conservation priority level of each vegetation community was analyzed within the boundaries of each individual ecoregion (that is, at the ecoregion scale). This resulted in 519 vegetation community/ecoregion combinations requiring analysis. In addition, each of the 119 vegetation communities was analyzed irrespective of the ecoregions (that is, at the Planning Area scale).

## Cross Tabulation of Vegetation Communities and Resource Management Status Categories

The acreage and percentage of each vegetation community that occurs within each RMS Category was calculated. This calculation was conducted for each vegetation community at the ecoregion scale as well as at the Planning Area scale. Sample results are presented in Table 1.

**Table 1.** Sample results of the cross tabulation between vegetation communities and Resourse Management Status (RMS) categories.

| Vegetation community (Holland 1986; Oberbauer, 1996) | Scale of analysis (Ecoregion or Planning Area) | Total acres | RMS I | | RMS II | | RMS III | | RMS IV | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Acres | Percent | Acres | Percent | Acres | Percent | Acres | Percent |
| 35210 Big Sagebrush Scrub | Central Mountains | 132 | 0 | 0 | 87 | 54 | 44 | 27 | 31 | 19 |
| | Northern Desert Slopes | 151 | 114 | 75 | 34 | 23 | 0 | 0 | 3 | 2 |
| | Northern Mountains | 572 | 37 | 6 | 74 | 13 | 0 | 0 | 462 | 81 |
| | South Desert Slopes | 206 | 67 | 33 | 74 | 36 | 23 | 11 | 41 | 20 |
| | Southern Mountains | 237 | 0 | 0 | 0 | 0 | 206 | 87 | 31 | 13 |
| | Planning Area | 1,328 | 218 | 16 | 270 | 20 | 273 | 21 | 567 | 43 |
| 37121 Granitic Southern Mixed Chaparral | Central Foothills | 2,048 | 0 | 0 | 0 | 0 | 945 | 46 | 1,103 | 54 |
| | Central Mountains | 90 | 0 | 0 | 0 | 0 | 6 | 6 | 84 | 94 |
| | Southern Foothills | 9,406 | 0 | 0 | 0 | 0 | 3,044 | 32 | 6,362 | 68 |
| | Planning Area | 11,544 | 0 | 0 | 0 | 0 | 3,995 | 35 | 7,549 | 65 |
| 37122 Mafic Southern Mixed Chaparral | Central Foothills / Southern Foothills | 1,320 | 0 | 0 | 88 | 7 | 910 | 69 | 322 | 24 |
| | Planning Area | 1,320 | 0 | 0 | 88 | 7 | 910 | 69 | 322 | 24 |
| 37210 Granitic Chamise Chaparral | Central Foothills | 2,583 | 0 | 0 | 10 | 0 | 2,446 | 95 | 126 | 5 |
| | Central Mountains | 7,579 | 2,629 | 35 | 1,598 | 21 | 2,787 | 37 | 565 | 7 |
| | Northern Desert Slopes | 1,480 | 1,141 | 77 | 140 | 9 | 0 | 0 | 199 | 13 |
| | Northern Mountains | 7,093 | 3,791 | 53 | 770 | 11 | 1,069 | 15 | 1,462 | 21 |
| | South Desert Slopes | 7,332 | 2,872 | 39 | 2,007 | 27 | 1,250 | 17 | 1,203 | 16 |
| | Southern Foothills | 10,259 | 3,048 | 30 | 520 | 5 | 2,306 | 22 | 4,384 | 43 |
| | Southern Mountains | 7,956 | 1,189 | 15 | 104 | 1 | 6,220 | 78 | 444 | 6 |
| | Planning Area | 44,282 | 14,670 | 33 | 5,150 | 12 | 16,079 | 36 | 8,383 | 19 |

## Calculation of a Conservation Level Index

To support interpretation of the cross tabulation data (Table 1), a Conservation Level Index (CLI) was created. The CLI distills the cross tabulation data into one number, allowing for easier comparison of each vegetation community's overall conservation status. The CLI is based on the relative proportion of each vegetation community that occurs within each RMS Category. The index ranges from 0 to 2, with 0 representing the lowest conservation level status, and 2 the highest. The formula used to derive the CLI is depicted in Figure 2.

Conservation Level Index (CLI) = ((% of Vegetation Community in RMS Category I) + (.75 * % of Vegetation Community in RMS Category II) + (.25 * % of Vegetation Community in RMS Category III) – (% of Vegetation Community in RMS Category IV) + 1

**Figure 2.** The formula used to derive the Conservation Level Index. RMS Category I lands are managed for ecological resources and are permanently protected; hence these lands are assigned a positive value. RMS Category II lands are managed for ecological resources, but are not permanently protected. Therefore, RMS Category II lands are assigned a positive value, but are weighted to reflect the lower assurance of conservation relative to RMS Category I lands. Maintenance of ecological resources on RMS Category III lands is much less certain, however most RMS Category III lands are public and we assume that, to a limited extent, ecological resources will be maintained. Therefore, RMS Category III lands are also assigned a positive value but are weighted to reflect the lower assurance of conservation relative to both RMS Category I and RMS Category II lands. It is assumed that the ecological resources on RMS Category IV lands will not be maintained and hence RMS Category IV lands are assigned a negative value. We determined that non-negative index values are easier to interpret. Hence, a value of 1 is added at the end of the formula to make the index values all positive.

## Prioritization of Vegetation Communities for Conservation Actions

Prioritization was based on quantitative and qualitative factors. However, as described below, final assignment of conservation priority levels was predominantly driven by quantitative criteria.

### Prioritization Based On Quantitative Criteria

The purpose of this analysis was to identify vegetation communities that should be a relatively high conservation priority on privately owned lands. The quantitative criteria for assigning priority levels were: (1) the current conservation status of each vegetation community (if a vegetation community is not well conserved it may be a higher priority); (2) the proportion of each vegetation community that occurs on privately owned land (if a large proportion occurs on privately owned land, it may be a higher priority); and (3) the rarity of each vegetation community (more rare vegetation communities may be a higher priority). To assign priority levels based on these three quantitative criteria; specific decision rules were developed. Development of the decision rules was an iterative process which required "fine tuning" of the rules until the results were deemed acceptable by a review team. The final decision rules that were used are depicted in Figure 3.

### Prioritization Based On Qualitative Factors

For prioritization, qualitative factors were also considered. For example, vegetation communities dominated by non-native species were always assigned a low priority level. Priority level assignments based upon qualitative factors were all documented. Of the 638 priority level assignments made, 632 assignments were based upon quantitative criteria and six assignments were based upon qualitative factors.

## Results

Some vegetation communities are common and well protected at the Planning Area scale, but are rare and not well protected within individual ecoregions. Similarly, some vegetation communities are common and well protected within individual ecoregions, but are rare and not well protected at the Planning Area scale. Therefore, the results were substantially different when the analysis was conducted at the Planning Area scale verses the ecoregion scale (Tables 2 and 3), (Figures 4 and 5). The difference in the results highlights the importance of conducting the analysis at different spatial scales in order to reveal vegetation communities which are higher conservation priorities in any given area.

**Table 2.** Acreage of private land within each conservation priority level when the analysis was conducted at the ecoregion scale.

| | Priority level | | | Total |
|---|---|---|---|---|
| | Low | Medium | High | |
| **Acres** | 107,357 | 93,754 | 124,050 | 325,160 |
| **Percentage** | 33 | 29 | 38 | N/A |

**Table 3.** Acreage of private land and number of vegetation communities within each conservation priority level when the analysis was conducted at the Planning Area scale.

| | Priority level | | | Total |
|---|---|---|---|---|
| | Low | Medium | High | |
| **Acres** | 193,213 | 49,405 | 82,543 | 325,160 |
| **Percentage of land** | 59 | 15 | 25 | N/A |
| **Number of vegetation communities** | 38 | 23 | 50 | 111 |
| **Percentage of vegetation communities** | 34 | 21 | 45 | N/A |

CRITERIA FOR PRIORITIZING VEGETATION COMMUNITIES AT THE SCALE OF INDIVIDUAL ECOREGIONS

1–5 PERCENT OF VEGETATION COMMUNITY ON PRIVATE LANDS

| | Acreage | | | |
|---|---|---|---|---|
| **CLI** | **<500** | **501–1,000** | **1,000–5,000** | **>5,000** |
| **0 – .5** | Medium | Low | Low | Low |
| **.6 – 1** | Medium | Low | Low | Low |
| **1.1 – 1.5** | Medium | Low | Low | Low |
| **1.6 – 2** | Medium | Low | Low | Low |

6–25 PERCENT OF VEGETATION COMMUNITY ON PRIVATE LANDS

| | Acreage | | | |
|---|---|---|---|---|
| **CLI** | **<500** | **501–1,000** | **1,000–5,000** | **>5,000** |
| **0 – .5** | High | High | Medium | Medium |
| **.6 – 1** | High | Medium | Medium | Low |
| **1.1 – 1.5** | Medium | Low | Low | Low |
| **1.6 – 2** | Medium | Low | Low | Low |

26–50 PERCENT OF VEGETATION COMMUNITY ON PRIVATE LANDS

| | Acreage | | | |
|---|---|---|---|---|
| **CLI** | **<500** | **501–1,000** | **1,000–5,000** | **>5,000** |
| **0 – .5** | High | High | High | Medium |
| **.6 – 1** | High | High | Medium | Medium |
| **1.1 – 1.5** | High | Medium | Low | Low |
| **1.6 – 2** | High | Medium | Low | Low |

51–100 PERCENT OF VEGETATION COMMUNITY ON PRIVATE LANDS

| | Acreage | | | |
|---|---|---|---|---|
| **CLI** | **<500** | **501–1,000** | **1,000–5,000** | **>5,000** |
| **0 – .5** | High | High | High | High |
| **.6 – 1** | High | High | High | High |
| **1.1 – 1.5** | High | High | Medium | Medium |
| **1.6 – 2** | High | High | Medium | Medium |

CRITERIA FOR PRIORITIZING VEGETATION COMMUNITIES PLANNING AREA SCALE

1–5 PERCENT OF VEGETATION COMMUNITY ON PRIVATE LANDS

| | Acreage | | | |
|---|---|---|---|---|
| **CLI** | **<1,000** | **1,001–10,000** | **10,000–25,000** | **>25,000** |
| **0 – .5** | Medium | Low | Low | Low |
| **.6 – 1** | Medium | Low | Low | Low |
| **1.1 – 1.5** | Medium | Low | Low | Low |
| **1.6 – 2** | Medium | Low | Low | Low |

6–25 PERCENT OF VEGETATION COMMUNITY ON PRIVATE LANDS

| | Acreage | | | |
|---|---|---|---|---|
| **CLI** | **<1,000** | **1,001–10,000** | **10,000–25,000** | **>25,000** |
| **0 – .5** | High | High | Medium | Medium |
| **.6 – 1** | High | Medium | Low | Low |
| **1.1 – 1.5** | Medium | Low | Low | Low |
| **1.6 – 2** | Medium | Low | Low | Low |

26–50 PERCENT OF VEGETATION COMMUNITY ON PRIVATE LANDS

| | Acreage | | | |
|---|---|---|---|---|
| **CLI** | **<1,000** | **1,001–10,000** | **10,000–25,000** | **>25,000** |
| **0 – .5** | High | High | High | Medium |
| **.6 – 1** | High | High | Medium | Low |
| **1.1 – 1.5** | High | Medium | Low | Low |
| **1.6 – 2** | High | Medium | Low | Low |

51–100 PERCENT OF VEGETATION COMMUNITY ON PRIVATE LANDS

| | Acreage | | | |
|---|---|---|---|---|
| **CLI** | **<1,000** | **1,001–10,000** | **10,000–25,000** | **>25,000** |
| **0 – .5** | High | High | High | High |
| **.6 – 1** | High | High | High | High |
| **1.1 – 1.5** | High | High | Medium | Medium |
| **1.6 – 2** | High | High | Medium | Medium |

**Figure 3.** Decision rules for assigning conservation priority levels. To determine the priority level of each vegetation community, the following steps are followed:
(1) Identify the correct column to use: The left column applies to prioritization of a vegetation community at the ecoregion scale; the right column applies to prioritization of a vegetation community at the Planning Area scale.
(2) Within the correct column, identify the correct table to use: The correct table is selected based upon the percentage of the vegetation community on privately owned lands, as depicted in the table captions.
(3) Within the correct table, identify the priority level: The box where the applicable row (based upon CLI Score) and column (based upon the acreage of the vegetation community) converge depicts the priority level to be assigned.

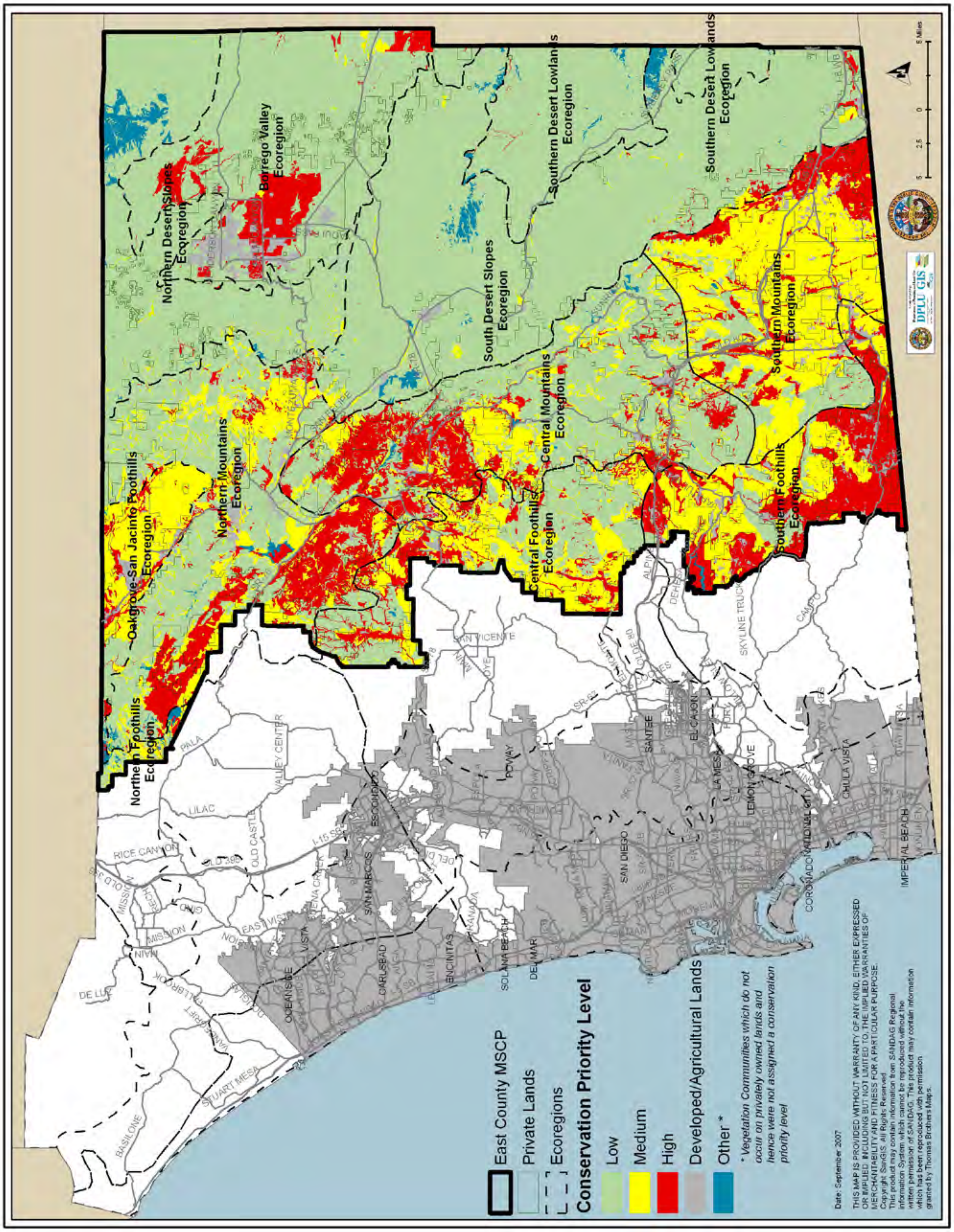



**Figure 4.** Conservation priority level of vegetation communities when the analysis was conducted at the ecoregion scale.

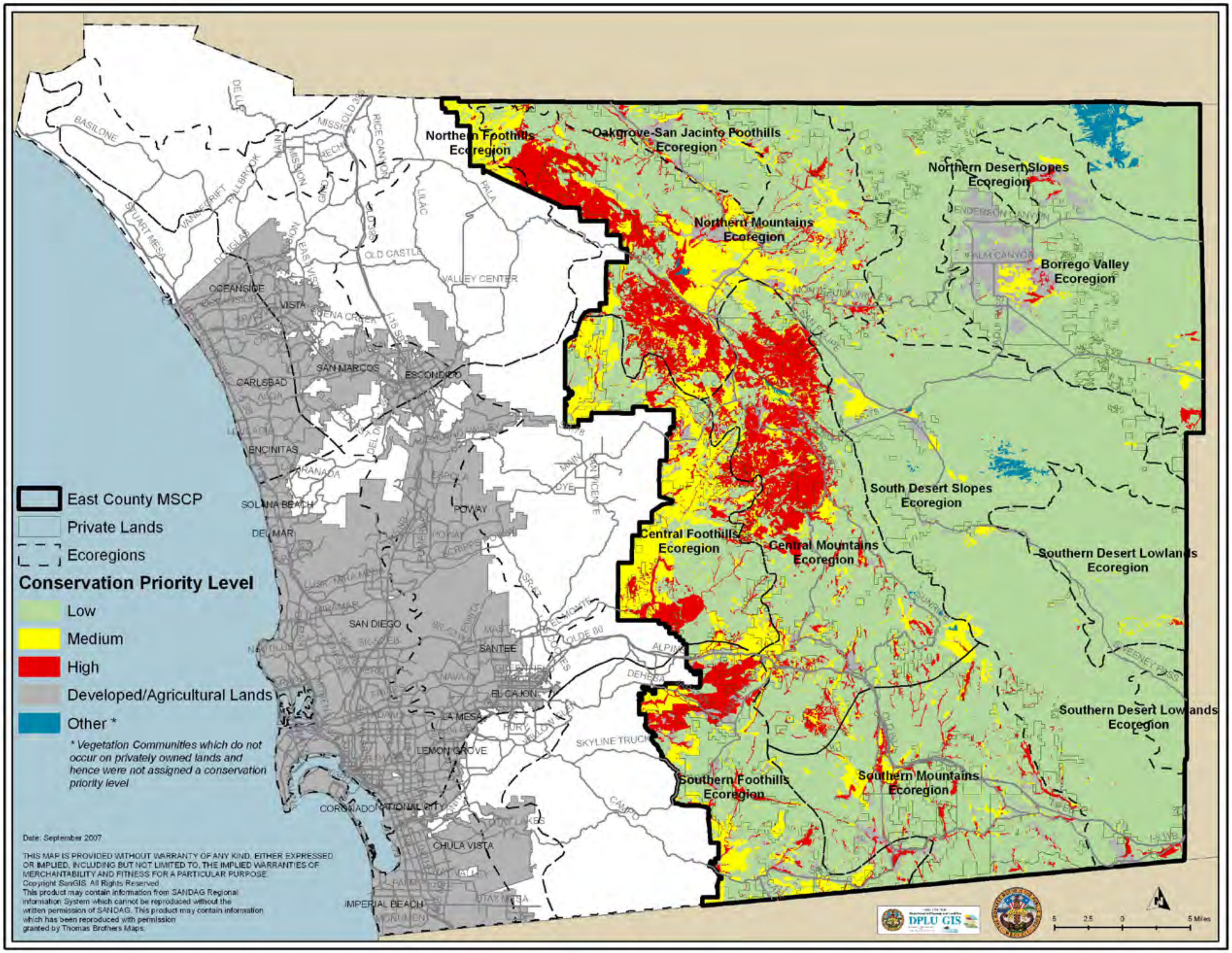



Figure 5. Conservation priority level of vegetation communities when the analysis was conducted at the Planning Area scale.

AQUATIC

# Improving Predicted Distribution Models for Riverine Species: An Example from Nebraska

Scott P. Sowa[1], Gust Annis[1], Michael E. Morey[1], and A. Garringer[1]

## Introduction

Modeling species distributions is in most instances, we believe, better if perceived as an exercise in modeling spatial patterns in habitat conditions. This perspective forces the modeler to think about factors and processes that influence local habitat and also to account for as many of these factors as possible in the modeling process. Local habitat conditions in riverine ecosystems (for example, pH, temperature, turbidity, permanence of flow, depths, velocities, substrate, cover, primary production, etc.) are influenced by a wide array of factors and processes operating at multiple spatial and temporal scales (Matthews 1998; Fausch et al. 2002). However, of primary importance is the interplay of watershed and local conditions (Hynes 1975; Richards et al. 1996; Rabeni and Sowa 2002). For instance, local substrate conditions are influenced by water and sediment delivery which are largely determined by watershed conditions and also local geomorphic conditions (for example, channel gradient) that affect sediment transport (Jacobson and Pugh 1999).

Until recently it has been essentially impossible to quantify watershed conditions for thousands of streams segments across large geographic areas (for example, entire states). For this and other reasons, species distribution models developed for the Missouri Aquatic GAP Project were based on only a handful of local habitat variables (Sowa et al. 2007). This pilot project illustrated the importance and utility of these local variables for modeling the distribution of riverine biota, however, the resulting models had relatively low accuracy. We recently completed a project, involving development of statewide predicted distributions for fishes of Nebraska, in which we were able to quantify both watershed and local conditions for essentially all stream segments in the state and use them in the modeling process. Results from this project, which is the focus of this article, provide a specific example of how using both watershed and local variables for modeling the distribution of riverine biota can significantly improve model accuracy.

## Methods

Methods used to develop the predicted distribution maps for fishes of Nebraska were essentially the same as those used in the Missouri Aquatic GAP Project (Sowa et al. 2005; Sowa et al. 2006). For the sake of brevity we will focus mainly on those elements of the methods that we believe led to improved accuracy of the Nebraska models compared to those of Missouri.

### Species Data and Range Maps

We obtained 6,623 fish community collection records from the Nebraska Game and Parks Commission (NGPC) and the Nebraska Department of Environmental Quality (NDEQ). Collections made between 1857 and 2001, include 2,914 distinct stream segments and contain 41,130 species occurrence records for the 100 fish species that occur in Nebraska.

Using ArcGIS 9.1 (ESRI 2005), each collection was geographically linked to the 1:100,000 11-digit Hydrologic Unit (HU) coverage. Digital range maps, based on 11-digit HUs, were constructed for each species, submitted for professional review, and revised as necessary.

[1.]Missouri Resources Assessment Partnership, School of Natural Resources, University of Missouri, 4200 New Haven Road, Columbia, MO 65201.

## GIS Base Layer for Predictive Modeling

Each collection also was geographically linked to the Nebraska 1:100,000 valley segment type (VST) coverage (Sowa et al. 2005), which served as the base layer for developing the predicted distribution models. The finest resolution ("linear spatial grain") of our predictions was the stream segment. Within Nebraska there are 62,941 individual stream segments in the VST coverage with an average length of 2.0 km.

## Predictor Variables

Eight local and 14 watershed variables were used as potential predictors (Table 1). Local variables were quantified for all 62,941 stream segments following the methods of Sowa et al. (2007) and represent the same variables used to predict species distributions in the Missouri Aquatic GAP Project. Watershed variables were quantified for all but 323 segments of the Missouri River due to a lack of time and money needed to quantify physiographic conditions throughout the enormous watersheds of these segments (for example see: Figure 1) (Sowa et al. 2006).

**Table 1.** Descriptions for the 23 local and watershed predictor variables.

| | |
|---|---|
| **Local variable** | |
| Flow | Binary variable that differentiates perennial and intermittent flow. |
| Temp | Binary variable that differentiates cold and warm water streams. |
| Linkr10 | A ten category description of stream size based on Shreve Link magnitude (Shreve 1966). |
| sdiscr_2c | Binary variable that differentiates stream segments that flow into either the same size stream or a larger stream. |
| grdseg10 | A ten category designation of stream segment gradient (m/km). |
| neb_geol | A 14 category variable designating the surficial geology through which each stream segment flows. |
| stxt4cat | A 4 category variable designating the general soil texture class through which each stream segment flows. |
| drn_grp | A 5 category variable designating the major drainage group in which a given stream segment occurs. |
| **Watershed variable** | |
| avegrd10 | Average gradient of all stream segments in the watershed. |
| hyda_p | Percent of watershed containing Hydrologic Soil Group A placed into ten categories. |
| hydb_p | Percent of watershed containing Hydrologic Soil Group B placed into ten categories. |
| hydc_p | Percent of watershed containing Hydrologic Soil Group C placed into ten categories. |
| hydd_p | Percent of watershed containing Hydrologic Soil Group D placed into ten categories. |
| stxt01_p | Percent of watershed containing Soil Surface Texture Class 1 (Sand) placed into ten categories. |
| stxt02_p | Percent of watershed containing Soil Surface Texture Class 2 (Loamy sand) placed into ten categories. |
| stxt03_p | Percent of watershed containing Soil Surface Texture Class 3 (Sandy loam) placed into ten categories. |
| stxt04_p | Percent of watershed containing Soil Surface Texture Class 4 (Silt loam) placed into ten categories. |
| stxt06_p | Percent of watershed containing Soil Surface Texture Class 6 (Loam) placed into ten categories. |
| stxt08_p | Percent of watershed containing Soil Surface Texture Class 8 (Silty clay loam) placed into ten categories. |
| stxt09_p | Percent of watershed containing Soil Surface Texture Class 9 (Clay loam) placed into ten categories. |
| stxt11_p | Percent of watershed containing Soil Surface Texture Class 11 (Silty clay) placed into ten categories. |
| stxt12_p | Percent of watershed containing Soil Surface Texture Class 12 (Clay) placed into ten categories. |


**Figure 1.** Map of Nebraska streams showing percentage of the watershed for each stream segment that contains soils classified as Hydrologic Soil Group A.

## Statistical Methods

Models were constructed with version 14 of the Classification Tree add-on of SPSS version 14.0 (SPSS, Inc. 2005). The specific modeling algorithm we used was Exhaustive CHAID, which is a modification of CHAID (Kass 1980) developed by Biggs et al. (1991). We generated species-specific input datasets containing a row for each of 6,623 collection records, a column for the binary species response variable (1=present, 0=absent), and columns for each of the 23 predictor variables.

We set the minimum number of collections allowable in a parent node equal to 10 percent and the number allowable in a child node equal to 1 percent of the total occurrence records for each species. We set the alpha level for splitting and merging equal to 0.05 and used the Bonferroni alpha adjustment to account for the increased likelihood of a Type One error associated with multiple comparisons (Bonferroni 1935).

The above methods were used to model distributions of most fish species. Alternative methods were used for species having too few occurrence records in order to generate a model and those species that do not occur outside of the Missouri River mainstem (Sowa et al. 2006).

# Model Outputs

## Probability of Occurrence

Each terminal node in a classification tree model provides a probability of occurrence for a given species under a certain set of conditions. These probabilities can be applied to an independent dataset using the suite of if/then model statements generated by SPSS. For each species we applied the resulting if/then statement model to the attribute table of the statewide 1:100,000 VST coverage (Figure 2). This process produced a column in the attribute table for that particular species which provides the probability of occurrence for each of the 62,618 stream segments in the state. However, all stream segments falling outside the professionally-reviewed geographic range were converted to zero probability.

## Presence

Calculating richness or diversity measures requires explicit yes or no statements about species presence, which are not provided with a continuous probability of occurrence. In many instances, modelers deem a species as being present at locations where it has greater than 50 percent probability of occurrence (Csuti and Crist 1998). However, due to sampling biases and inefficiencies, species with low detection probabilities rarely have occurrence probabilities greater than 50 percent and would therefore never be predicted as "present." In fact, most fish species modeled in this project have maximum occurrence probabilities below 50 percent (Sowa et al. 2006).

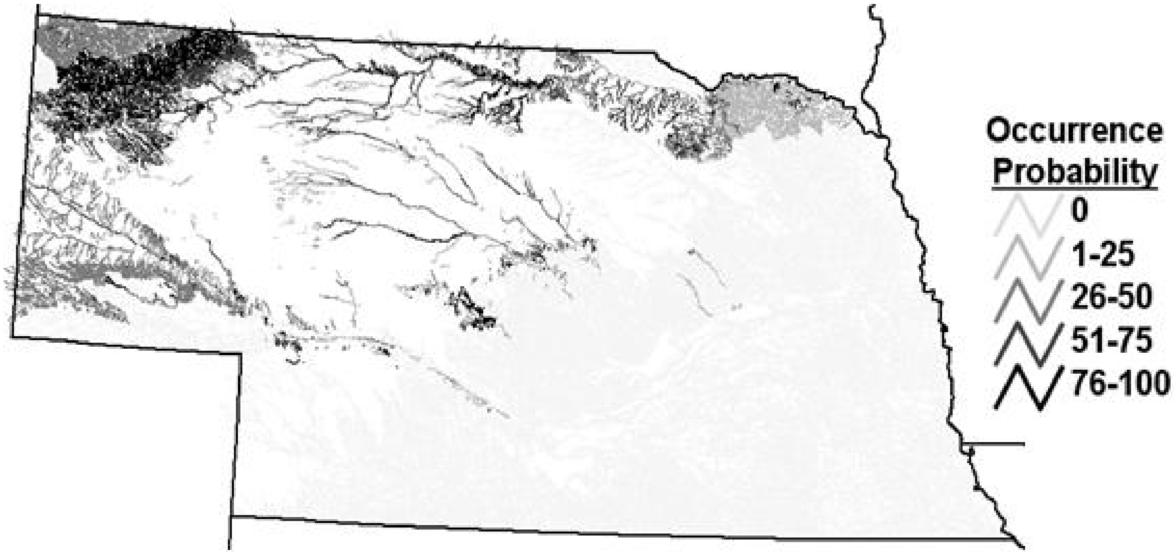



**Figure 2.** Map of predicted occurrence probabilities for the longnose dace (*Rhinichthys cataractae*) throughout Nebraska.

To overcome this problem we used the "relative-50%" rule developed by Sowa et al. (2005) to generate a binary presence/absence model for each species. Specifically, for each model we identified the terminal node having the highest occurrence percentage that also contained at least 50 collection records. We then multiplied this highest percentage by 0.5 and selected all terminal nodes with occurrence probabilities greater than or equal to this percentage (Figure 3). These selected segments were then attributed with a value of 1 to denote presence, while all other segments were attributed with a 0 in a separate attribute field for each species. Again, all segments outside of the geographic range of the species were attributed with a 0.

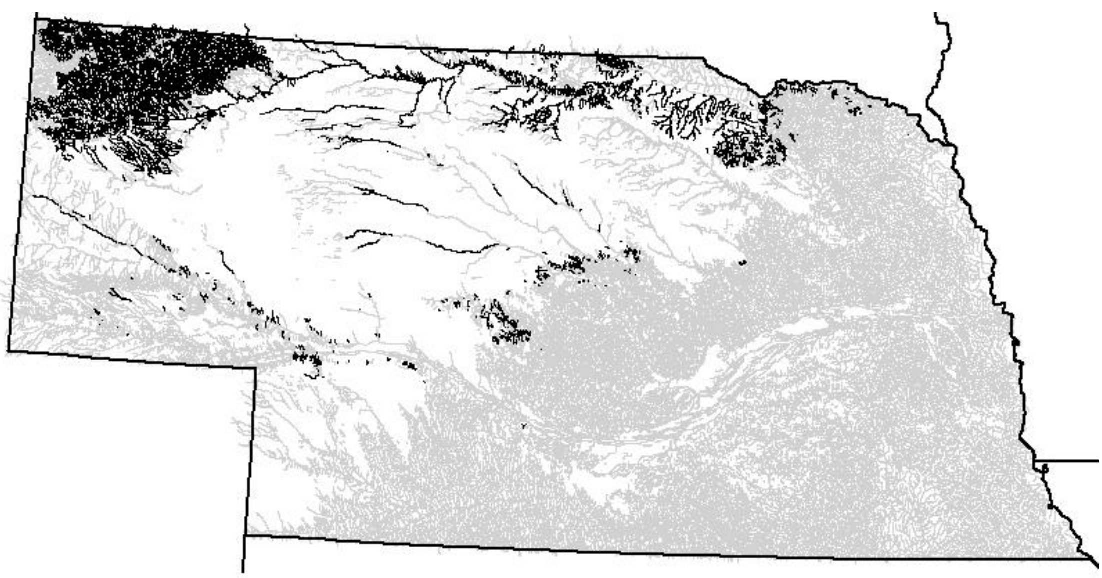


**Figure 3.** Map of predicted occurrence (in black) for the longnose dace (*Rhinichthys cataractae*) throughout Nebraska. Predicted occurrence was based on a relative 50 percent rule (see text). In this instance the highest occurrence probability, with sufficient samples, was 91 percent. This map shows all segments with occurrence probabilities greater than or equal to (0.5 times 91) or 45.5 percent. Overall accuracy of this model was 92 percent.

## Results and Discussion

Lacking an independent dataset, we assessed the accuracy of the presence models against the input data used to create the models. For each species, we calculated omission (species occurs, but not predicted), commission (species predicted, but does not occur), and overall error rates. Species-specific error rates are provided in Sowa et al. (2006) and the average error rates across all 100 species are provided in Table 2. The overall error rate was only 8 percent (Table 2). This is significantly less than the 49 percent overall misclassification rate for fishes in the Missouri Aquatic GAP Project. Average omission (3 percent) and particularly commission (6 percent) error rates were also significantly lower than what was achieved in Missouri (Table 2) (MO: omission: 10 percent; commission: 48 percent).

Considering that local habitat conditions in rivers and streams are significantly influenced by physiographic conditions in the watershed (Hynes 1975; Frissell et al. 1986), we believe the addition of 15 watershed variables as potential predictors was the most important factor leading to the improved accuracy of the models in Nebraska compared to Missouri. These watershed variables dominated our classification tree models, which contrasts with what Oakes et al. (2005) determined in a similar project that modeled fish distributions throughout the Big Blue River watershed in Kansas and Nebraska. However, as Wiens (1989; 2002) points out, such differences in the perceived importance of explanatory variables should be expected among studies when either the spatial grain or extent of the investigation differs. While the variables and spatial grain of our modeling efforts were similar to that of Oakes et al. (2005), the significantly larger spatial extent of our project (entire state vs. single watershed) covered a much wider range of physiographic conditions that influence stream habitat, which likely led to the increased predictive capabilities of the watershed variables in our models.

There were two other notable factors that also likely increased the accuracy of the models we developed for Nebraska. First, we had nearly twice as many collection records for Nebraska fishes (6,623) than we did for Missouri (3,723). All other things being equal, increasing the number of species occurrence records should increase model accuracy. Second, the collections for Nebraska covered a longer time frame (NE: 1857-2001; MO: 1900–1999) and had a substantially higher number of historical and reference-quality samples. Collections from highly disturbed locations will tend to decouple relations between species occurrence and natural features of the environment, which was the objective of our modeling efforts. The higher number of historical and reference-quality samples likely improved model accuracy.

**Table 2.** Average accuracy statistics for occurrence models developed for 100 Nebraska fishes.

| | Average (percent) | Minimum | Maximum |
|---|---|---|---|
| Omission | 3 | 0 | 19 |
| Commission | 6 | 0 | 33 |
| Overall | 8 | 0 | 38 |

Finally, we need to point out one last and very important difference between the models developed for Missouri and those developed for Nebraska. This difference does not pertain to the issue of accuracy, but rather the utility of the end products. The classification tree models we generated with the methods presented above are extremely complex. Manually applying hundreds of resulting if/then model statements (for a single model) to an independent dataset is essentially impossible to do for hundreds of species, not to mention doing this task without human error. Because of this problem, for Missouri we were only able to generate binary presence/absence attributes in the attribute file of the statewide VST coverage for each species, despite having models that provided occurrence probabilities.

Improvements in the SPSS software (SPSS 2005), since we modeled species distributions in Missouri, allow the resulting models to be applied to an independent dataset. This software advancement allowed us to attribute the Nebraska VST coverage with continuous probabilities of occurrence for each species. These continuous probabilities provide users with significantly more information on which to base decisions and greater flexibility in their use. In fact, we are currently working with the Nebraska Game and Parks Commission to use these occurrence probabilities to develop optimized sampling designs for locating additional populations of twelve at-risk fish species.

Predicted distribution models are a fundamental component of all GAP projects (Csuti and Scott, 1991), which is why the National Gap Analysis Program has been at the forefront of meeting this critical data need for conservation planning across the United States (Maxwell, 2006). GAP also has been a leader in addressing many research and technical issues surrounding this complex endeavor as evidenced by the number of peer-reviewed publications on this topic by gap practitioners (see http://gapanalysis.nbii.gov/). Considering the importance of species distribution data for resource planning and management (cf. Scott et al. 2002; Brooks et al. 2004; Pressey 2004), it is essential that we continually strive to develop the most accurate and precise distribution models possible.

Until recently it has been essentially impossible to quantify watershed conditions for tens of thousands of individual stream segments across large geographic areas. Fortunately, recent technological and methodological advancements have allowed us to overcome this obstacle, but it is still somewhat costly and time consuming to generate these watershed data. However, we believe that all future efforts to model the distributions of riverine biota across large regions should take the extra time, money and effort to incorporate watershed variables into the modeling process. The gains in model accuracy certainly outweigh the additional costs.

## References Cited


Biggs, D., B. de ville, and E. Suen. 1991. A method of choosing multiway partitions for classification and decision trees. *Journal of Applied Statistics* 18: 49-62.

Bonferroni, C.E. 1935. Il calcolo delle assicurazioni su gruppi di teste. Pages 13-60 In *Studi in Onore del Professore Salvatore Ortu Carboni*. Rome: Italy.

Brooks, T.M., G.A. da Fonseca, and A.S.L. Rodrigues. 2004. Species, data, and conservation planning. *Conservation Biology* 18:1682-1688.

Csuti, B. and P. Crist. 1998. Methods for assessing accuracy of animal distribution maps (version 2.01). In *A Handbook for Conducting Gap Analysis*. USGS Gap Analysis Program, Moscow, Idaho. Available online at: http://www.gap.uidaho.edu/handbook

Csuti, B. and J.M. Scott. 1991. Mapping wildlife diversity for gap analysis. *Western Wildlands* Fall: 13-18.

ESRI 2005. ArcGIS 9.1. Environmental Systems Research Institute, Redlands, CA.

Fausch, K.D., C.E. Torgersen, C.V. Baxter, and H.W. Li. 2002. Landscapes to riverscapes: bridging the gap between research and conservation of stream fishes. *Bioscience* 52(6):483-498.

Frissel, C.A., W.J. Liss, C.E. Warren, and M.D. Hurley. 1986. A hierarchical framework for stream habitat classification: viewing streams in a watershed context. *Environmental Management* 10: 199-214.

Hynes, H.B.N. 1975. *The stream and its valley*. Verh. Int. Theor. Ang. Limnol. 19:1-15.

Jacobson, R.B. and A.L. Pugh. 1999. Riparian vegetation controls on the spatial pattern of stream-channel instability, Little Piney Creek, Missouri: U.S. Geological Survey Water-Supply Paper 2494.

Kass, G. 1980. An exploratory technique for investigating large quantities of categorical data. *Applied Statistics* 29: 119-127.

Matthews, W.J. 1998. *Patterns in Freshwater Fish Ecology*. Chapman and Hall, New York, NY.

Maxwell, J. 2006. Role of GAP data in state wildlife plan development: opportunities and lessons learned. In Maxwell et al., eds. *Gap Analysis Bulletin No. 14:4-10*. USGS/BRD/Gap Analysis Program. Moscow, ID. Available online at http://www.gap.uidaho.edu/Bulletins/14/Maxwell.htm

Oakes, R.M., K.B. Gido, J.A. Falke, J.D. Olden, and B.L. Brock. 2005. Modelling of stream fishes in the Great Plains, USA. *Ecology of Freshwater Fish* 14:361-374.

Pressey, R.L. 2004. Conservation planning for biodiversity: Assembling the best data for the job. *Conservation Biology* 18:1677-1681.

Rabeni, C.F. and S.P. Sowa. 2002. A landscape approach to managing the biota of streams and rivers. Pages 114-142 In J. Liu and W. Taylor, eds. *Integrating Landscape Ecology Into Natural Resource Management*. Cambridge University Press. Cambridge, MA.

Richards, C., L.B. Johnson, and G.E. Host. 1996. Landscape-scale influences on stream habitat and biota. *Journal of Fisheries and Aquatic Sciences* 53 (Suppl. 1):295-311.

Scott, J.M., P.J. Heglund, M.L. Morrison, J.B. Haufler, M.G. Raphael, W.A. Wall, and F.B. Samson, eds. 2002. *Predicting Species Distributions; Issues of accuracy and scale*. Island Press, Washington, D.C.

Sowa, S.P., D.D. Diamond, R. Abbitt, G. Annis, T. Gordon, M.E. Morey, G.R. Sorensen, and D. True. 2005. *A Gap Analysis for Riverine Ecosystems of Missouri. Final Report*, submitted to the USGS National Gap Analysis Program. Moscow, ID. 1675 pp.

Sowa, S.P., G. Annis, M.E. Morey, and A. Garringer. July 2006. Developing predicted distribution models for fish species in Nebraska. Final report submitted to the USGS National Gap Analysis Program. Moscow, ID. 489 pp.

Sowa, S.P., G. Annis, M.E. Morey, and D.D. Diamond. 2007. A gap analysis and comprehensive conservation strategy for riverine ecosystems of Missouri. *Ecological Monographs* 77(3): 301-334.

SPSS Inc. (2005). *SPSS Base 14.0 for Windows User's Guide*. SPSS Inc., Chicago IL.

Wiens, J.A. 1989. Spatial scaling in ecology. *Functional Ecology* 3:385-397.

Wiens, J.A. 2002. Riverine landscapes: taking landscape ecology into the water. *Freshwater Biology* 47:501-515.

# Ohio Aquatic Gap Analysis

By S. Alex. Covert[1], Stephanie P. Kula[1], and Laura A. Simonson[1]

The Ohio Aquatic GAP pilot project applied the GAP concept to aquatic—specifically, riverine—data that included all continuously flowing streams in Ohio. Ohio Aquatic GAP was coordinated by the Ohio Water Science Center, U.S. Geological Survey (USGS) and sponsored by the Biological Resources Discipline of the USGS. Through regular stakeholder meetings and expert reviews, Ohio Aquatic GAP involved participation from State and Federal agencies, non-profit conservation organizations, and universities.

The mission of GAP is to provide regional, coarse-scale assessments of the conservation status of native animal species and to facilitate the application of this information to land-management activities. Ohio Aquatic GAP accomplished this and met the goal of identifying gaps in the conservation of native aquatic animal species through

- Mapping aquatic habitat types,
- Mapping the predicted distributions of fish, crayfish, and bivalves,
- Documenting the presence of aquatic species in areas managed for conservation,
- Providing GAP results to the public, planners, managers, policy makers, and researchers, and
- Building cooperation with multiple organizations to apply GAP results to state and regional management activities.

## Stream Classification and Mapping of Aquatic Habitat Types

To characterize the aquatic habitats available to Ohio fish, crayfish, and bivalves, a classification system was developed and mapped using eight separate enduring physical features of streams which, when combined, formed 5,269 separate physical habitat types. The eight variables used in the classification include:

- Shreve link (a measure of stream size)
- Downstream Shreve link (a measure of stream connectivity and size)
- Sinuosity
- Gradient
- Bedrock
- Stream temperature
- Character of glacial drift, and
- Glacial-drift thickness

The perennial streams of the 1:100,000 National Hydrography Dataset were used as the streams base layer. Elevation data used to characterize gradient were derived from the 30 meter National Elevation Dataset. Data for classification of geologic attributes included maps of bedrock geology and unconsolidated aquifers from the Ohio Department of Natural Resources (ODNR). Stream temperature data were from the U.S. Environmental Protection Agency's (USEPA) Storage and Retrieval (STORET) Database.

## Predicted Animal Species Distributions

Potential distribution models were developed for 130 fish, 70 bivalve, and 17 native crayfish species. These models were based on the variables describing the physical habitat types, variables indicating the major drainage basins and Omernik's Level III ecoregion, and the sampled locations of the fish, crayfish, or freshwater bivalve species.

The databases of fish, crayfish, and freshwater bivalves collected from Ohio streams during the periods 1978–2001, 1920–2003, and 1850–2001, respectively was compiled by Ohio Aquatic GAP. Crayfish and freshwater bivalve species were modeled only if historical records were accompanied by recent records (1978–2003) to prevent extirpated species from skewing the analysis. The available biological data were collected by a number of sources and

[1] U.S. Geological Survey, Ohio Water Science Center, Columbus, OH

represent the wide diversity of stream sizes and types in Ohio. Collecting agencies for fish include the Ohio Environmental Protection Agency (Ohio EPA), ODNR, Ohio Department of Transportation (ODOT), and USGS. Sources of available crayfish data include the Cleveland Museum of Natural History, The Ohio State University Museum of Biological Diversity, Ohio EPA, and personal collections. The available freshwater bivalve database was obtained from The Ohio State University Museum of Biological Diversity, Division of Mollusks.

The modeling software package DesktopGarp (Genetic Algorithm for Rule-Set Production) was used in most cases for predicting potential distributions of each species individually. GARP creates ecological niche models that represent the locations where the environmental conditions, as represented by the various physical habitat type layers, suggest that the species would be able to maintain populations. An alternative method, extrapolation, was used when there were not enough known occurrence points to run the DesktopGarp model. Both the GARP and extrapolation modeling methods created potential distributions and may not represent current reality based, for example, on poor water quality or presence of a competitor species.

## Land Stewardship and Conservation Status

The Ohio Aquatic Gap Analysis Project compiled a map of public and private conservation lands and classified the lands into four status categories (status 1 through status 4) by the degree of protection offered based on management practices. This map also will be used by the terrestrial Ohio Gap Project. Status 1 denotes the highest, most permanent level of maintenance, and status 4 represents the lowest level of biodiversity management, or unknown status. The results of this mapping show that only about 3.7 percent of the state's land (4.3 percent if lakes and reservoirs are also included) is protected for conservation, either publicly or privately.

## Analysis Based on Stewardship and Conservation Status

Conservation areas that presently protect a portion of Ohio's aquatic biodiversity were identified through the analysis of the distributions of species and conservation lands on a 14-digit hydrologic unit (14-HU) scale. Hydrologic units are representations of watersheds used by the USGS to organize hydrologic data. Results show that 22 fish species and 2 bivalve species had predicted distributions exclusive of conservation lands classified as status 1 or status 2. Nine of these fish species are considered rare, threatened, or endangered in the state.

Ohio Aquatic Gap also identified 14-HUs or subwatersheds as potential conservation-priority areas (Figure 1). Based primarily on measures of predicted species richness and taxa richness, 75 (out of 504) 14-HUs in the Lake Erie Basin and 67 (out of 1,291) 14-HUs in the Ohio River Basin were identified for their conservation potential. Specifically, Ohio Aquatic GAP used percentages of summed potential species-richness values. The largest number of fish species from a stream class was identified and used to set the upper percentile criteria for each major drainage basin. Each 14-HU was then measured against a percentage of this maximum species number. Ohio Aquatic GAP used three levels of criteria: 75th, 90th, and 95th percentiles.

The 14-HUs meeting the 95th-percentile criterion for a taxon were kept regardless of attainment of other criteria because they represent the highest in potential species richness for each taxon in each major drainage basin. The 14-HUs meeting the 90th-percentile criterion were kept if two or more taxa, such as fish and bivalves, overlapped for this criterion. Lastly, 14-HUs meeting the 75th-percentile criterion were kept only if all three taxa agreed at the 75th-percentile level (or higher). The three criteria were used together to identify areas with different aquatic assemblages or groups of animals. Ohio Aquatic GAP did not give one individual criterion more weight than another. Ohio Aquatic GAP did give more weight to 14-HUs meeting an increasing number of criteria. For example, a 14-HU that met the 75th percentile for crayfish, the 90th percentile for bivalves, and the 95th percentile for fish would be given more weight when considering conservation priorities than a 14-HU that only met the 95th percentile for fish.

## Data Use and Availability

The primary products of the Ohio Aquatic GAP project are geospatial databases for land stewardship, stream-habitat types, and predicted distribution models for native fish, crayfish, and bivalves. Associated Ohio Aquatic GAP geospatial databases include mapped locations of fish, crayfish, and bivalves. These data, along with the final report, are available from the USGS Publications Warehouse at http://pubs.usgs.gov/of/2006/1385/.

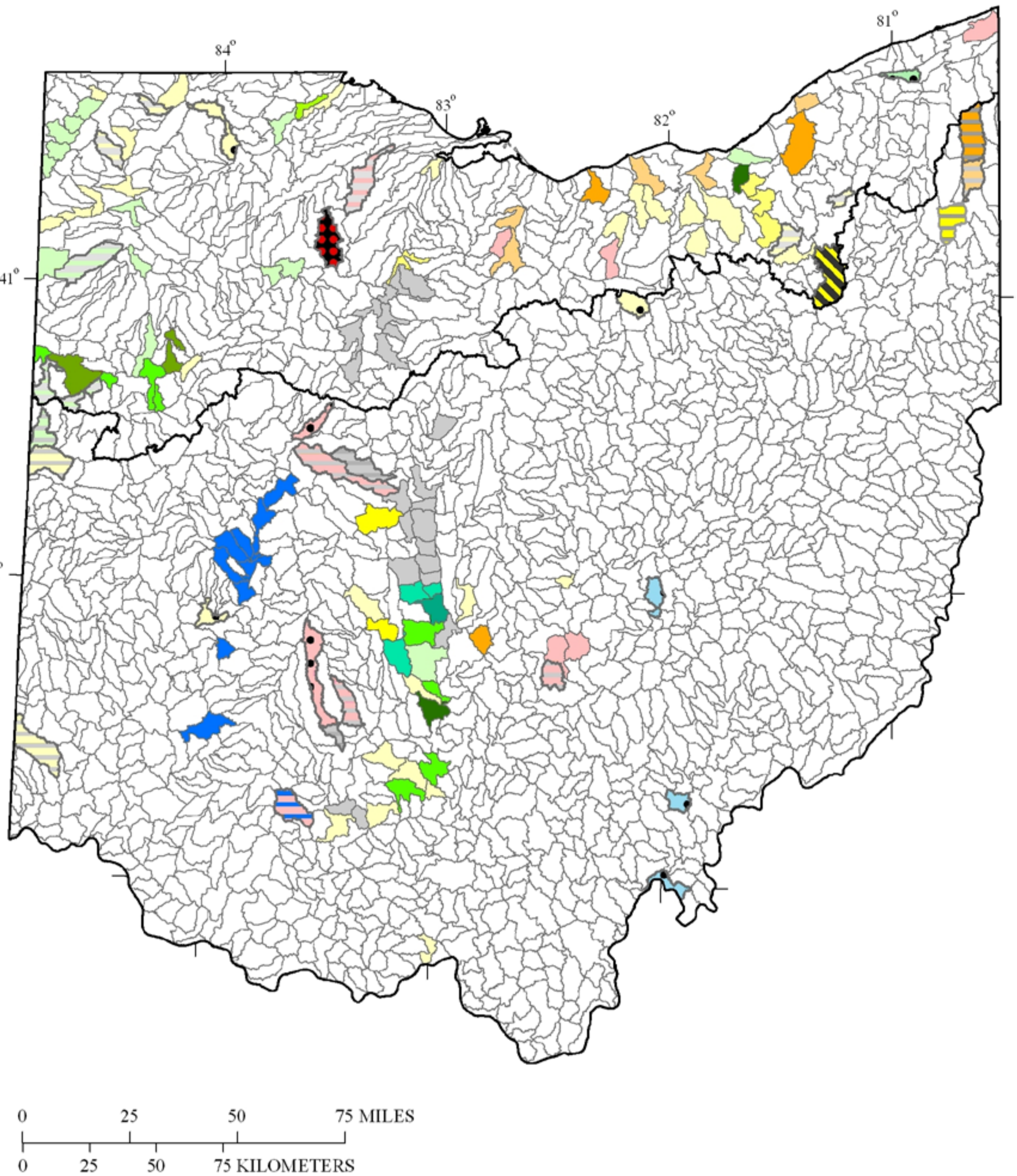



**Figure 1.** Species richness of fish, crayfish, and bivalve species, by 14-digit hydrologic unit (14-HU), relative to major drainage basin and stream size. Number in parenthesis indicates the highest percentile criteria achieved. These 14-HUs represent areas of potentially high conservation priority. A solid black line separates the Lake Erie Basin in the north from the Ohio River Basin in the south.

**EXPLANATION**
**Aquatic species richness**
**[predicted]**

**Lake Erie drainage basin**

**Small streams (1st order)**

- fish (95%)
- fish (95%) bivalves (95%)

**Small AND medium streams (1st, 2nd, 3rd order)**

- fish (95%)
- crayfish (95%)

**Medium streams (2nd and 3rd order)**

- fish (95%)
- crayfish (95%)
- fish (90%) bivalves (95%)

**Large streams (4th order and larger)**

- fish (95%)
- crayfish/bivalves (75%) fish (95%)
- crayfish (95%)
- fish (90%) crayfish (95%)
- fish (95%) crayfish (95%)
- fish/crayfish/bivalves (75%)
- fish/bivalves (90%)
- bivalves (90%) fish (95%)
- fish (90%) bivalves (95%)
- fish (95%) bivalves (95%)
- crayfish (75%) fish (95%) bivalves (95%)

**Ohio River drainage basin**

**Small streams (1st order)**

- fish (95%)
- crayfish (95%)
- bivalves (95%)

**Medium streams (2nd and 3rd order)**

- bivalves (75%) crayfish (90%) fish (95%)
- fish/crayfish/bivalves (75%)
- fish (95%)
- bivalves (75%) fish (90%) crayfish (95%)
- bivalves (75%) fish/crayfish (90%)
- crayfish (95%)
- fish (95%) and bivalves (95%)

**Large streams (4th order and larger)**

- fish/crayfish/bivalves (75%)
- fish (95%)
- crayfish/bivalves (75%) fish (95%)
- bivalves (75%) fish/crayfish (90%)
- crayfish (95%)
- fish/bivalves (90%)
- bivalves (90%) fish (95%)
- crayfish (75%) fish/bivalves (90%)
- crayfish (75%) bivalves (90%) fish (95%)
- crayfish (75%) fish (95%) and bivalves (95%)

**Cold water streams**

- cold water
- cold water and crayfish (95%)

**Figure 1.**—Continued

# FINAL REPORT SUMMARIES

## Hawaii Gap Analysis Project

Dwight H. Matsuwaki[1] and Dr. Barbara A. Gibson[1]

### Introduction

The Hawaii Gap Analysis Project (HI-GAP) is a cooperative effort between private, State and Federal conservation partners, coordinated by the Hawaii Biodiversity and Mapping Program (formerly Hawaii Natural Heritage Program). HI-GAP began in 1999 to assess the distribution and conservation status of biodiversity in the State under existing land ownership and management regimes. Our objectives were to (1) map the natural land cover of the state, at the association level where possible (Federal Geographic Data Committee 1997); (2) predict the potential occurrence of native terrestrial vertebrate species and vascular plants across Hawaii; (3) produce a database of protected lands within the State; (4) document the occurrence of natural communities and selected native species in lands managed for the long-term conservation of biodiversity; (5) make all HI-GAP information available to decision-makers, researchers, and other interested persons; and (6) build partnerships through development of this data.

### Land Cover

Statewide and individual island land cover maps for the State of Hawaii circa 1999 to 2005 were prepared from Landsat Thematic Mapper (TM) satellite data. The spatial resolution of the land cover map is 30 by 30 meters, over multiple iterations to achieve cloud-free coverage. The legend for the statewide land cover map contains 37 classes. Moreover, 71 island-specific classes were mapped to offer greater detail when dealing with the individual islands. An accuracy assessment was completed only for the statewide land cover classes due to financial and time constraints.

### Accuracy Assessment

The overall results from the accuracy assessment of the 37 statewide land cover classes were 44.13 percent, with a Kappa of 0.42. A total of 1,439 sample polygons were used. An error matrix was created that gave the breakdown for the Primary and Secondary class designations that were assigned by field experts using their knowledge of the area in question by reviewing high resolution imagery and ground truthing. While all 1,439 sample polygons were assigned a Primary class, only 504 sample polygons were assigned a Secondary class. Accuracy Assessment based on grouping of the prefix code of 11 classes gave an overall accuracy of 62.71 percent, with a Kappa of 0.55. An accuracy assessment based on 10 major land cover categories gave an overall accuracy of 66.25 percent, with a Kappa of 0.55.

### Terrestrial Vertebrate and Native Plant Distributions

Hawaii does not have any native herpetiles and only one terrestrial mammal (Hawaiian hoary bat). Thus, predicted distribution maps were developed for 43 native resident bird species that represent all major taxonomic groups that occur in Hawaii. Range maps were developed by expert opinion for two species that lacked sufficient location data. Presence data were used to identify occupied locations for 20 species with discrete habitat requirements, including waterbirds and seabirds. The remaining 21 species had other environmental constraints incorporated with its habitat association to HI-GAP's land cover classes. Most islands are typically characterized by two types of bird richness hotspot. The first corresponds to

[1] Hawaii Biodiversity and Mapping Program (HBMP), Center for Conservation Research and Training, Universiy of Hawaii at Manoa, Honolulu.

very low elevations and is associated with concentrations of waterbirds and seabirds. The second occurs in montane forested habitats, with most species represented being single-island endemics. The richest of these hotpots are Kaua‘i, three disjunctive areas on Hawaii, and northern East Maui.

Hawaii’s native biota is considered disharmonic, and its biodiversity is strongly dominated by plants and invertebrates. Therefore, to better reflect biodiversity distributions, vascular plant taxa were included. The focus was on Federally listed taxa and only those species for which all infraspecific taxa were federally listed, excluding species considered to be extinct in the wild. The resulting list of 230 focal species represents nearly one-fourth of the vascular flora of the Hawaiian Islands. Richness of endangered plant species is typically highest in the mesic zone, and at mid-elevation. Among islands with substantial mesic and wet habitats, the lowlands of the Waianae Mountains stand out as having especially high richness of endangered plant species. This contrasts to bird species richness, which is largely at higher elevations and in wetter habitats.

## Land Stewardship

Under GAP Status Categories approximately 700,600 hectares of the land in Hawaii is managed by public agencies with 12.2 percent under Federal management, 37.3 percent under state jurisdiction and 0.7 percent under county jurisdiction (Table 1). Lands managed by The Nature Conservancy, a non-profit conservation organization, account for approximately 0.3 percent of the land. Private land owners are responsible for management of approximately 49.6 percent. Status 1 and status 2 lands occupy 221 and 279,298 hectares, respectively, which combined is 17 percent of the state. Federal stewards are responsible for 63.6 percent of status 1 and 2 lands. 6 percent of Federal public lands were multiple-use and assigned a status of 3. Lands managed by State government stewards (78.1 percent) were assigned a status of 3, and the remaining 22.6 percent of State public lands was assigned a status of 4.

Under Hawaii GAP Management Intent Status Categories Status 1 and Status 2 lands occupy 228,822 ha and 61,805 ha, respectively, which combined is 18 percent of the State (Table 2). Federal stewards are responsible for 61.2 percent of status 1 and 2 lands. Some Federal public lands (3.8 percent) were multiple-use and assigned a status of 3. Lands managed by State government stewards (61.5 percent) were assigned a status of 3, and the remaining 19.3 percent of State public lands was assigned a status of 4.

The combined percentage of area for Status 1 and 2 are roughly the same for both National GAP and HI-GAP indices. But HI-GAP determined that it is important to note that a major difference exists between Status 1 and 2 in Hawaii.

**Table 1.** National Gap Stewardship Status by ownership category.

| | National gap status | | | | Total |
|---|---|---|---|---|---|
| | Status 1 | Status 2 | Status 3 | Status 4 | |
| | Hectares (percent of total) | | | | |
| Private lands | 1 (0.2) | 16,597(5.9) | 62,823 (15.4) | 740,958 (76.5) | 820,378 (49.6) |
| The Nature Conservancy | – | 4,750 (1.7) | – | – | 4,750 (0.3) |
| County | – | – | 1,961 (0.5) | 8,948 (0.9) | 10,909 (0.7) |
| State | 102 (46.1) | 75,789 (27.1) | 305,539 (75.0) | 156,789 (16.2) | 538,219 (32.5) |
| Department of Hawaiian Home Lands | – | 4,545 (1.6) | 12,797 (3.1) | 61,718 (6.4) | 79,060 (4.8) |
| Federal lands | 118 (53.7) | 177,618 (63.6) | 24,238 (6.0) | 235 (<0.1) | 202,210 (12.2) |
| **Total (percentage of State)** | **221 (0.01)** | **279,298 (17)** | **407,358 (25)** | **968,649 (58)** | **(100)** |

**Table 2.** Hawaii Gap Stewardship Status by ownership category.

| | HI-GAP management intent status | | | | Total |
|---|---|---|---|---|---|
| | Status 1 | Status 2 | Status 3 | Status 4 | |
| | Hectares (percent of total) | | | | |
| Private lands | 14,362 (6.3) | 6,983 (11.3) | 213,756 (33.8) | 585,278 (79.9) | 820,378 (49.6) |
| The Nature Conservancy | 4,750 (2.1) | – | – | – | 4,750 (0.3) |
| County | – | – | 5,076 (0.8) | 5,834 (0.8) | 10,909 (0.7) |
| State | 32,401 (14.2) | 49,397 (79.9) | 372,515 (58.9) | 83,906 (11.5) | 538,219 (32.5) |
| Department of Hawaiian Home Lands | – | 4,793 (7.8) | 16,530 (2.6) | 57,736 (7.75) | 79,060 (4.8) |
| Federal lands | 177,309 (77.5) | 631 (1.0) | 24,105 (3.8) | 164 (0.25) | 202,210 (12.2) |
| **Total (percentage of State)** | **228,822 (14)** | **61,805 (4)** | **631,981 (38)** | **732,918 (44)** | **(100)** |

## Gap Analysis

The Hawaii GAP analysis used the more general 37 land cover classes across the State. Approximately 32 percent of the State is covered by 22 native vegetation land cover classes. Unvegetated or sparse land cover represents about 17 percent and much of this is young lava, cinders and ash on the island of Hawaii and Maui. Approximately 40 percent of the State is covered by five alien vegetation land cover classes, and approximately 6 percent of the State is in agriculture. The two mixed native and alien vegetation land cover classes indicate the ongoing conversion of native land by invading alien vegetation. The high coverage of alien vegetation on conversion from native to alien dominated land cover highlights the invasive species problems faced by natural resource managers in Hawaii.

Most of the State's land cover is unprotected (approximately 83 percent Status 3 and Status 4). Only about 17 percent of the State's land cover is in the more protected Status 1 and Status 2 land cover categories. However, less than 8 percent of this Status 1 or Status 2 land cover is native vegetation. Approximately 24 percent of the State's native vegetation land cover is in Status 3 or Status 4. An examination of data for 42 native bird species and 227 native plant species show that many occur in status categories 3 and 4 on lands held by private land owners and by the State. Approximately 80 percent of predicted native bird species ranges and 85 percent of predicted native plant species ranges are on State and private lands in status categories 3 and 4.

Effective conservation actions should result in a reassignment of Status 3 or Status 4 native vegetation into Status 1 or Status 2 land cover categories. If successfully done, especially with implementation of protective, active management, the State's remaining native vegetation, about 32 percent of the State's land cover, would be conserved. Private land owners, the State of Hawaii, and the U.S. Military are the major holders of critical native biotic elements within Status 3 and Status 4 land cover categories. Successful conservation of native biodiversity will require their participation.

While, benefiting Hawaii's biodiversity, reassignment of native vegetation from an unprotected to protected status would heavily favor wet forest and higher elevation areas, and leave out much of Hawaii's remaining mid- and lower elevation land areas. Further analyses of the GAP land cover data can provide a focused assessment of each native land cover class by island, and aid in directing management and protection to areas of greatest need.

# Wisconsin Gap Analysis Project

Jill Maxwell[1]

## Introduction

The Wisconsin Gap Analysis Project (WI-GAP) began in 1994 to assess the distribution and conservation status of biodiversity in the State under existing land ownership and management regimes. The project's objectives were to (1) map vegetation types; (2) map predicted distribution of terrestrial vertebrates; (3) document occurrence of inadequately represented vegetation types in special management areas; (4) document occurrence of inadequately represented terrestrial vertebrate species in special management areas; and (5) make all information available to resource managers and land stewards in a readily accessible format to provide resources that will help maintain vertebrate species richness within the State. This was accomplished by identifying:

- areas of unique species richness that may lack adequate protection under land ownership and management regimes;
- species whose habitat requirements are not protected by current management practices; and
- habitat types or geographical associations of habitats that may lack adequate protection under current land ownership and management regimes.

## Land Cover

The classification of land cover data was performed in three phases. In the first phase, a detailed ground survey of land cover was done. This survey was used to create two data sets of known land cover types collected at known locations in the state. These data were used to (1) help build the routines used to classify the satellite data, and (2) check the accuracy of the final land cover data.

In the second phase, the satellite data were classified. The state was divided into 28 spectrally consistent classification units (SCCU). These SCCUs represented areas of fairly uniform land cover within the boundaries of a single satellite scene. Ground truth data collected within each SCCU along with the state's wetland inventory data were used to create the computer processing routines used to classify the data. Once each SCCU had been classified, they were combined to create the statewide data set.

The third phase of this project was accuracy assessment. The second set of ground truth data were saved to be used at this time, to see if the computer classification process produced an acceptable product.

A map of the land cover of Wisconsin circa 1993 was prepared from satellite data collected in 1991, 1992, and 1993. Multiple sets of data were collected, so seasonal land cover changes could be detected. The spatial resolution of the land cover map is 30 by 30 meters. The geo-rectified Multi-Resolution Land Characteristics (MRLC) data were processed according to the protocol published in the UMGAP Image Processing Protocol (Lillesand et al. 1998), at http://www.umesc.usgs.gov/umgap/documents.html. The classified data (except URBAN) were generalized from their original 30-meter resolution to a 1 acre area of any four contiguous like pixels using a clump-sieve-fill algorithm devised within Imagine and described in detail in the inhouse technical procedures document. Strata were clipped at the SCCU boundary, converted from Imagine v.8.3 files into ArcInfo Grids, projected into WTM83/91, and then joined for continuous coverage.

## Accuracy Assessment

The source TM data were geometrically corrected by the Earth Resources Observation and Science (EROS) Data Center to fit the U.S. Geological Survey (USGS) 1:24,000-scale quadrangle maps. Accuracy standards were on the order of a root mean square error (RMSE) no greater than 1 pixel, or ± 30 meters. The data were projected using the software program ArcInfo. The selected spectral resampling algorithm used during the reprojection process was the "nearest neighbor." Positional accuracy of the projected data was evaluated empirically by overlaying the TM data with a vector data set, that was known to meet the National Map Accuracy Standards at 1:24,000 scale (USGS digital line

[1] National Gap Operations Office, University of Idaho Gap Analysis Program, Moscow.

graph data). The fit of the overlay was evaluated at a scale of 1:40,000, which is the minimum recommended for display of land cover data. While the projecting of raster data introduced some degree of spatial error, it was assumed that the stated positional accuracy of the original data was preserved as much as possible. This subjective evaluation proved satisfactory. The highest classification accuracies generally were in the south-central part of the state (the SCCU centered on Rock County and also the SCCU covering the Door County peninsula). Lowest accuracies generally were in the far northwest. Open water was usually resolved quite accurately. However, detection of open water when interspersed with wetlands was somewhat less accurate.

## Terrestrial Vertebrate Distributions

Potential distribution maps were developed for 376 terrestrial vertebrate species comprising 259 species of breeding birds, 65 species of mammals, 18 species of amphibians, and 34 species of reptiles. The individual range maps created for the modeling project, were developed using the U.S. Environmental Protection Agency's (USEPA) Environmental Monitoring and Assessment Program (EMAP) hexagon data as a template. Listings of Wisconsin species (by taxonomic class) were obtained from the Wisconsin Department of Natural Resources (DNR).

Mammals were the most difficult group of animals to model, as current range and habitat information were unavailable. While the modeling project was under way, the Wisconsin DNR was in the middle of a 5-year assessment project to determine the current range, extent, and habitat preferences of the State's mammal population. These data were not available to the modelers, instead most available information was several years old. One resource that did provide the "best fit" one-stop resource for range information is a recently published field guide (Tekiela 2005). The bird models varied in complexity from locating general land cover references to identifying particular habitats that occurred within a specific distances of other habitats, or potential habitat areas of a specific size. The site specific habitat requirements of many reptile and amphibian species make these animals difficult to model with TM-interpreted data. Many have specific ground cover or moisture requirements, which are not recorded by satellite data collectors. Several hydrology data sets were used to help refine the models. Most errors associated with these models are probably errors of commission. The modeling process was aided by several recent publications containing range and habitat information for these animals.

Accuracy assessments of the models have not been completed at this time. The models and their data will be provided to the Wisconsin DNR for their use in their assessment projects of the state's wildlife. One goal of the 5-year assessment project of the state's mammal populations is to model potential habitat using the Wisconsin Initiative for Statewide Cooperation on Landscape Analysis and Data (WISCLAND) data, and updated habitat preference and potential range information obtained from the field surveys.

## Land Stewardship

Approximately 8.24 percent of the land in Wisconsin is managed by public agencies. Approximately 1.84 percent of the land in Wisconsin occurs within the boundaries of lands governed by Native American tribal governments. Private land owners are responsible for management of approximately 82 percent. Status 1 and status 2 lands occupy 1.7 and 2.5 percent, respectively, which combined is slightly more than 4.2 percent of the state and 26.75 percent of the area in public and private conservation lands.

## Gap Analysis

**Urban Areas:** The urban land cover groups comprise 2,269 square kilometers of the state, about 1.6 percent. Most of these areas have been assigned status ratings of 4. Their land managers and owners are unknown.

**Agricultural Areas:** About 44,750 square kilometers of the state, almost 31 percent, is classified as agricultural. Most of these lands (30.5 percent of the state) are assigned to status 4, with unknown owners and land managers. Most areas classified as agricultural in areas of known land managers, and most occurred on lands managed by the Wisconsin DNR (0.21 percent).

**Grasslands:** About 15,553 square kilometers (10.7 percent) of the state was mapped as grasslands. Most of these lands (10 percent of the state) are assigned to status 4, with unknown owners and land managers. Most remaining grasslands are in areas managed by the Wisconsin DNR (0.25 percent of the state), within county forests (0.2 percent of the state), on military bases (0.05 percent), and are on Fish and Wildlife Service (FWS) managed lands (0.03 percent).

**Forests–Upland:** Approximately 54,400 square kilometers (37.5 percent) of the state was mapped as forested. Most of these lands (26.6 percent of the state) are assigned to status 4, with unknown owners and land managers. Almost 4.4 percent of the state is within county forests. The Forest Service lands (national), cover just over 3 percent of the state.

Lands managed by the Wisconsin DNR which were classified as forested comprise 1.8 percent of the state. Forested areas classified as Native American/Tribal lands comprise 1.2 percent of the state.

**Wetlands - Non Forested (includes shrub wetlands):** Approximately 10,700 square kilometers (7.4 percent) of the state was mapped as non-forested wetlands. Most of these lands (5 percent of the state) are assigned to status 4, with unknown owners and land managers. Just over 0.92 percent of the state was classified as non-forested wetlands managed by the Wisconsin DNR, and another 0.77 percent of the state is in non-forested wetlands on county managed properties. Non-forested wetlands on lands managed by the Forest Service comprise 0.33 percent of the state. Non-forested wetlands on lands managed by the FWS comprise 0.13 percent of the state.

**Wetlands - Forested:** Approximately 9,800 square kilometers (6.7 percent) of the state was mapped as forested wetlands. Most of these lands (4.4 percent of the state) are assigned to status 4, with unknown owners and land managers. The next largest block of forested wetlands are on properties managed by county governments, 0.83 percent of the state. The Forest Service forested wetlands comprise 0.60 percent of the state. The Wisconsin DNR forested wetlands comprise 0.56 percent of the state. Forested wetlands on Native American/Tribal properties comprise 0.17 percent of the state, and forested wetlands on lands managed by the FWS comprise 0.09 percent of the state.

## References Cited

Lillesand, S., J. Chipman, D. Nagel, H. Reese, M. Bobo, and R. Goldman. 1998. *Upper Midwest Gap Analysis Program Image Processing Protocol*. U.S. Geological Survey Environmental Management Technical Center, Onalaska, WI.

Tekiela, S. 2005. *Mammals of Wisconson Field Guide*. Cambridge, MN: Adventure Publications.

# Nebraska Gap Analysis Project

G.M. Henebry[1], M.R. Vaitkus[1], and J.W. Merchant[1]

## Introduction

The Nebraska Gap Analysis Project (NE-GAP) began in 1996 to assess the distribution and conservation status of biodiversity in the State under existing land ownership and management regimes. Our objectives were to (1) map land cover linked to dominant vegetation types; (2) map predicted distribution of terrestrial vertebrates; (3) document the representation of natural vegetation communities and animal species in areas managed for the long-term maintenance of biodiversity; and (4) make all information available to resource managers and land stewards in a readily accessible format.

## Land Cover

A map of the land cover of Nebraska circa 1992 was prepared from Landsat Thematic Mapper (TM) imagery from 1991–93. The spatial resolution of the land cover map is 30 by 30 meters.

The legend for the land cover map is shown in Table 1.

**Table 1.** Land cover legend for Nebraska.

| Land cover value | Land cover name |
|---|---|
| 1 | Ponderosa pine forests and woodlands |
| 2 | Deciduous forest/woodland |
| 3 | Juniper woodland |
| 4 | Sandsage shrubland |
| 5 | Sandhills upland prairie |
| 6 | Lowland tallgrass prairie |
| 7 | Upland tallgrass prairie |
| 8 | Little bluestem-gamma mixedgrass prairie |
| 9 | Western wheatgrass mixedgrass prairie |
| 10 | Western shortgrass prairie |
| 11 | Barren/sand/outcrop |
| 12 | Agricultural fields |
| 13 | Open water |
| 14 | Fallow agricultural fields |
| 15 | Aquatic bed wetland |
| 16 | Emergent wetland |
| 17 | Riparian shrubland |
| 18 | Riparian woodland |
| 19 | Low intentisity residential |
| 20 | Commercial/industrial/transportation |

## Accuracy Assessment

The overall accuracy was 29 percent, with a significant Kappa value of 0.201. Although the classification was far from random (Khat z-score=12.74), there was considerable confusion between land cover classes, especially among the grassland types. Aggregating the cover classes into five broader categories lead to a significant increase in overall accuracy (61 percent). These broader categories corresponded to the landscape matrix within which organisms need suitable habitat to persist: grasslands, woodlands, shrublands, wetlands, and anthropolands.

Although the aggregation of the land cover classes into the broader categories was mostly straightforward, one category "anthropolands" deserves some comment. Human influences on the landscape matrix and habitat availability can occur in many ways; however, the direct transformation of land to intensive human use is the most obvious. Anthropolands include the lands used for dense human settlement and commercial activity as well as active and fallow agricultural lands. Given the significant area covered by reservoirs, lakes, and farm ponds in Nebraska, it could be argued that class 13 "open water" should also be placed within the anthropolands category instead of the wetlands category. However, wildlife use of open water habitats is substantial and has more in common with wetlands than with lands intensively used by humans.

Challenging the aggregated classes with the best of our five collections of field data lead to an overall accuracy of 71 percent. A simple accuracy assessment treats each class as having equivalent importance. A more refined approach is to weight the columns of the confusion matrix by abundance or prevalence of the class. The aggregated categories have the following area extents: grasslands (53.9 percent), anthropolands (40.2 percent), woodlands (3.0 percent), wetlands (2.0 percent), and shrublands (0.9 percent). Applying this approach to the aggregated categories significantly increased the overall accuracy to 73 percent using all field data and to 79 percent using the best collection of field data alone.

[1.]University of Nebraska-Lincoln ([1]currently South Dakota State University).

## Terrestrial Vertebrate Distributions

Potential distribution maps were developed for 332 terrestrial vertebrate species comprising 193 species of breeding birds, 78 species of mammals, 14 species of amphibians and 47 species of reptiles. Range limits of each species were delineated on a grid of 40 $km^2$ hexagons using a statistical modeling approach that combined locality records from museum voucher specimens and curated biological surveys with a suite of environmental variables. Alternatively, the models relied on cues in the literature coupled with the suite of environmental variables. The accuracy of the vertebrate potential distribution models was assessed using different locality records and, given the data availability and modeling approach, omission rates were selected as the focus for specific and taxon accuracy assessments. Excluded from the accuracy assessment were 65 species with state-wide distributions and 57 species with no independent observations. Omission rates were calculated differently across taxa, depending on the quality of the data available for accuracy assessment. For birds, data were available at two spatial resolutions: by county and by Breeding Bird Survey (BBS) route. Average and median omission rates for birds were, respectively, 7.2 and 0.0 percent at BBS level and 24.3 and 0.0 percent at the county level. For mammals, data were available at two levels: point locations for voucher specimens in the Nebraska State Museum and at the county level. Average and median omission rates for mammals were, respectively, 19.9 and 13.6 percent at point locations and 7.1 and 0.0 percent at the county level. For amphibians and reptiles, data were only available at the county level and the average and median omission rates were, respectively, 3.7 and 0.0 percent. The consistent pattern of the average omission rate being substantially larger than the median omission rate indicates that only a few species ranges are poorly modeled.

## Land Stewardship

Approximately 1.79 percent of land in Nebraska is managed by public agencies with 1.15 percent under Federal management and 0.64 percent under State jurisdiction. About 0.79 percent of the land in Nebraska occurs within the boundaries of lands governed by five Native American tribal governments. Lands managed by non-profit conservation organizations account for 0.25 percent of the land in Nebraska. Private land owners are responsible for management of about 97.17 percent.

Status 1 and status 2 lands occupy 490.3 $km^2$ and 734.8 $km^2$, respectively, which combined is approximately 0.6 percent of the State and 30 percent of the area in public and private conservation lands. Federal stewards are responsible for 62 percent of status 1 and 2 lands. Sixty percent of Federal public lands were multiple-use and assigned a status of 3. Twelve percent of lands managed by State government stewards were assigned a status of 4, and the remaining 88 percent of state public lands was assigned a status of 3.

## Gap Analysis

Approximately 97.4 percent of the prairie land cover category occurs on private lands; Federal agencies and State land departments manage 1.7 and 0.5 percent of prairie, respectively. Lands governed by the Native American Tribes account for 0.79 percent land cover category. Private land owners are responsible for stewardship of about 92.6 percent of the wetland land cover category. Federal agencies have responsibility for 4.1 percent of the wetland land cover category.

# REGIONAL PROJECT REPORTS

## Northwest Regional GAP (NWGAP)

Jocelyn Aycrigg[1]

### Introduction

The Northwest Gap Analysis Project (NWGAP) began in September 2004. The project will update GAP datasets for Wyoming, Montana, Idaho, Oregon, and Washington.

### Northwest Gap Analysis Project Objectives

NWGAP has three primary goals:

1. Create consistent and current data products.
2. Maintain common information system:
   a. Classify ecological systems for land cover mapping,
   b. Conduct deductive and inductive species modeling,
   c. Determine map boundaries and conservation status of preserves and protected areas, and
   d. Conduct a region-wide gap analysis
3. Distribute data and conduct outreach.

**Land cover:** Figure 1 shows the status of land cover mapping in the Northwest. Map zone 1, which is complete and available in draft form from National Gap Analysis Program at http://www.gap.uidaho.edu/Northwest/home.htm.

***Map zones 2 and 7:*** Started in May 2006 in partnership with the U.S. Forest Service and Oregon State University. To be completed by October and December 2007, respectively.

***Map zones 8 and 9:*** Non-forested areas were completed by U.S. Geological Survey (USGS) Sagebrush and Grassland Ecosystem Map Assessment Project (SAGEMAP, http://sagemap.wr.usgs.gov). We partnered with U.S. Forest Service and Oregon State University to complete the forested areas. These data are complete and available in draft form from the National Gap Analysis Program (See Northwest Gap Analysis Project web page: http://www.gap.uidaho.edu/Northwest/home.htm).

***Map zones 10 and 21:*** Began in May 2006 and being carried out by personnel in our Moscow office of the National Gap Analysis Project. Map zone 10 was projected to be completed by August 2007 and 21 by October 2007.

***Map zone 18:*** Completed by USGS SAGEMAP (see http://sagemap.wr.usgs.gov). These data will be combined into the regional vegetation map for the Northwest in 2009.

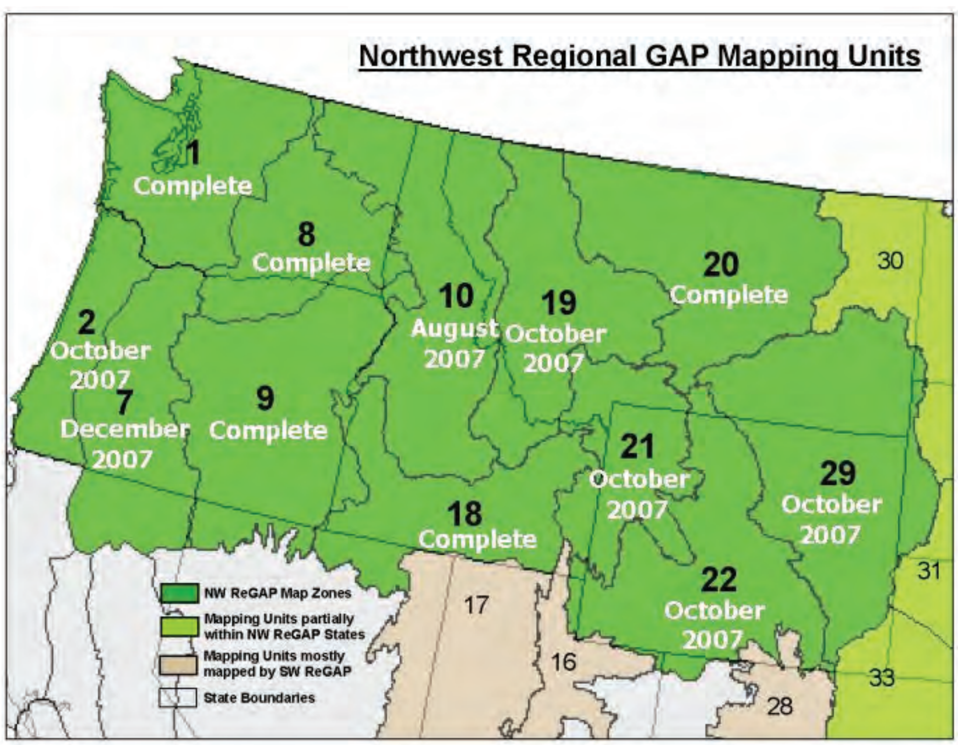



**Figure 1.** Status of Northwest Regional GAP land cover mapping as of December 2007. Mapping is organized by LANDFIRE Map Zones.

[1] National Gap Operations Office, Moscow, Idaho.

***Map zone 19:*** Started in May 2005 and is scheduled to be completed in October 2007. Being conducted by personnel in the Moscow office of the National Gap Analysis Project.

***Map zone 20:*** Started in October 2005 with work being done by Sanborn Solutions. These data are complete and available in draft form from the National Gap Analysis Program (See Northwest Gap Analysis Project web page: http://www.gap.uidaho.edu/Northwest/home.htm).

***Map zone 22 and 29:*** Began in July 2006 with work being done by Sanborn Solutions. These data are scheduled to be completed by October 2007.

**Vertebrate modeling**: This part of the northwest project started in September 2005. Currently, more than 2 million species occurrence records have been gathered from all five Northwest Natural Heritage Programs. The records are being filtered for duplicate records. Region-wide data are also being incorporated.

Each of the five Natural Heritage Programs is assisting us with collecting species occurrence data, providing biological expertise, and building review teams within their respective states. However, the Wyoming Natural Diversity Database at the University of Wyoming in Laramie, WY, is coordinating the species modeling efforts.

The five Natural Heritage Programs are:

- Wyoming Natural Diversity Database, University of Wyoming, Laramie, WY,
- Idaho Conservation Data Center, Idaho Dept. of Fish and Game, Boise, ID,
- Montana Natural Heritage Program, University of Montana, Missoula, MT,
- Washington Natural Heritage Program, Washington Department of Natural Resources, Olympia, WA, and
- Oregon Natural Heritage Information Program, Institute for Natural Resources, Oregon State, University, Portland, OR.

The intent of this approach was to divide the modeling work, so that primary experts and data holders for particular species are responsible for those species (for example, Natural Heritage biologists model species they know and track). With this approach, Natural Heritage biologists divide the compilation of point data and aggregate data for the species they will model in their states, while other species will be modeled centrally in Laramie. Museum data sources will be compiled centrally and distributed to the states that will use them in models.

The Natural Heritage Programs were selected because they have existing occurrence data, expertise, and infrastructure that cannot be replicated. Each program acts as a central clearinghouse for occurrence data. An added benefit is that each program has occurrence data for only one state, which eliminates the duplication of records and makes data compilation easier. All programs use the same software, standards, and methodologies including a common database. This ensures individual records match in type and format. The database is continually reviewed, quality checked, and updated, which minimizes duplicate records and keeps the database available for re-analysis at any time.

We intend to map the range (total areal extent occupied by a species), distribution (spatial arrangement of environments suitable for occupation by a species, and habitat (environments with the combination of resources and conditions that promote occupancy, survival, and reproduction by a species) of each species. We are attempting to make regional maps more useful to local land managers by taking this approach.

NWGAP is taking two modeling approaches. First a deductive modeling approach, which was the standard approach used by state-based Gap projects and the Southwest Gap Analysis Project; and second, an inductive modeling approach, which also is being used in the Southeast Gap Analysis project.

In a deductive modeling approach information from experts and literature reviews regarding habitat associations is synthesized first. Then, land cover data are used to predict a species' distribution based on its habitat associations. The species' distribution is then refined using species occurrence records. This modeling approach works well for species with abundant information regarding habitat associations and limited occurrence records. However, it tends to over predict when habitat associations and land cover types are too general and when species occur in habitat that is difficult to define using satellite imagery (for example, riparian habitat).

In an inductive modeling approach empirical observations are used to derive objective conclusions. A predicted species distribution is based on environmental parameters (for example, elevation, climate gradients) at known points of occurrence. This modeling approach works well when presence and absence data are available and there are numerous occurrence records for a species with good spatial distribution. It tends to under predict if only limited or unevenly distributed occurrence data are available and if false negatives exist in data. Our approach is to combine the strengths of both modeling approaches to improve the species distribution maps.

**Stewardship mapping:** The Northwest stewardship data will start being developed in autumn 2007 with personnel in the National Gap Analysis Program in Moscow, Idaho. If you have data that you believe would be important to include in these data, please contact Jocelyn Aycrigg.

Please check the Northwest Gap Analysis Project web site for future updates (http://www.gap.uidaho.edu/Northwest/home.htm).

# Southeast Gap Analysis Regional (SE-GAP)

Alexa McKerrow[1]

## Introduction

The datasets for the Southeast Gap Analysis Project (SE-GAP) are nearly complete with provisional datasets for each of the three major components: land cover, vertebrate species modeling, and land management stewardship. Preliminary analyses are underway and we are continuing to work with partners to apply the new datasets in conservation applications. The Online Gap tool is serving the provisional land cover and stewardship dataset for interactive viewing (http://www5.basic.ncsu.edu/). The Southwest and North Carolina Gap Analysis data are available as well for interactive queries and the Puerto Rico Gap dataset is the next priority.

In September 2007, the Southeast Regional Gap Project and the National Gap Program co-hosted the 2007 National Gap Analysis Conference in Asheville, North Carolina.

## Land Cover Mapping

The map of the Ecological Systems and anthropogenic cover types is complete for the nine state region (AL, FL, GA, KY, MS, NC, SC, TN and VA; Figure. 1). In the course of the project we had a unique opportunity to work with the U.S. Geological Survey's (USGS) National Land Cover Dataset (NLCD) (Vogelman et al. 2001) and National Oceanic and Atmospheric Administration Coastal Change Analysis Program in the development of impervious surface; canopy closure and land cover for a large proportion of the NLCD 2001 in the region. We also worked closely with NatureServe Ecologists to apply the Ecological Systems classification, which evolved in part as a response to previous Gap mapping efforts and the recognition of a need for a classification that was ecologically meaningful and that could be mapped with mid-scale remote sensing imagery. More recently, we have been able to collaborate with the Landfire Project on a technical basis, sharing data and methods and reviewing intermediate products.

For the Southeast we have mapped more than 150 land cover classes, using various methods based on the available ancillary data, with map zone- and sometimes map class-specific approaches. We relied heavily on the NLCD 2001, with anthropogenic classes (urban, row crop, pasture/hay) coming directly from that dataset. For the natural land cover types a combination of expert derived rules, decision tree modeling, traditional supervised, and unsupervised classification techniques were incorporated. In addition to these techniques, we incorporated the use of pattern recognition software to provide a spatial context for mapping of some land cover classes. NatureServe developed range maps for the Ecological Systems of the region, using primarily U.S. Environmental Protection Agency Level III and IV Ecoregions.

## Vertebrate Species Modeling

Distribution models for 614 vertebrate species have been drafted and reviews are underway (see examples in Figure 2). These models are based on deductive modeling based on extensive literature reviews and expert opinion. Primary datasets used in the creation of these models include known range, SE-GAP land cover, hydrology (National Hydrologic Data), elevation (National Elevation Data), and landforms. Typically, omission and commission rates are used to validate models by comparing available local species occurrence lists with predicted distributions. Frequently, those data are not sufficient, so the Alabama Gap Project developed an approach based on Bayesian Belief Networks and Decision Support Models to assess the need to revise individual species models. The Alabama models are being revised as indicated by that process and the process of the expert review expanded to the remaining regional models.

## Land Management Stewardship

Central to the analysis of a species' or plant community's status is the need to characterize how the lands that support it are being managed. The GAP Stewardship Database provides this in the form of a spatial representation of the ownership and management intent by parcel. Criteria for categorizing the stewardship include permanence of protection, management intent, and the scope and extent of management activities that are permitted.

[1] North Carolina State University, Raleigh, North Carolina.

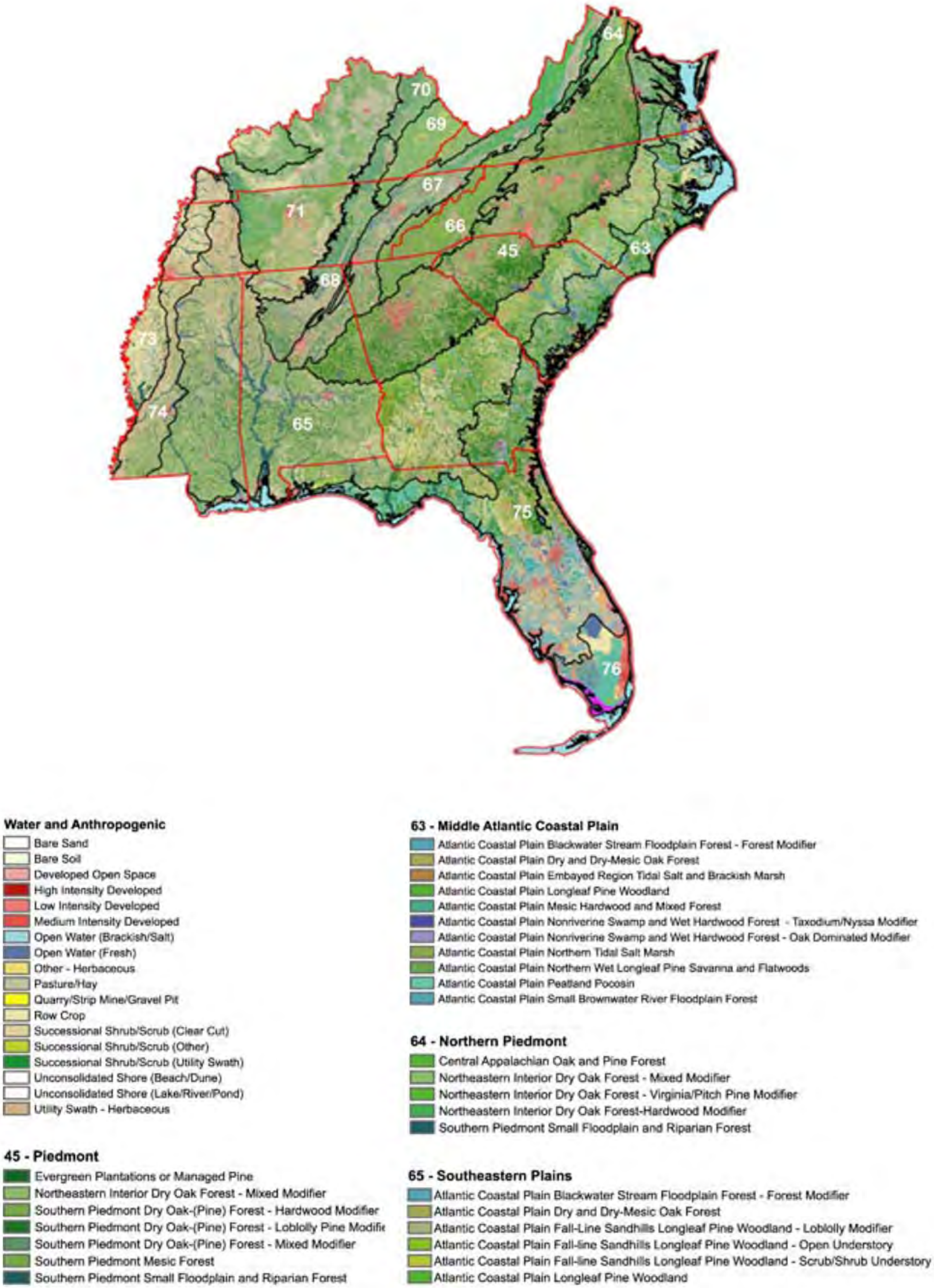



**Figure 1.** Southeast Gap Analysis draft land cover.

- Atlantic Coastal Plain Mesic Hardwood and Mixed Forest
- Atlantic Coastal Plain Small Blackwater River Floodplain Forest
- Atlantic Coastal Plain Small Brownwater River Floodplain Forest
- East Gulf Coastal Plain Interior Shortleaf Pine-Oak Forest - Hardwood Modifier
- East Gulf Coastal Plain Interior Shortleaf Pine-Oak Forest - Mixed Modifier
- East Gulf Coastal Plain Interior Upland Longleaf Pine Woodland - Loblolly Modifier
- East Gulf Coastal Plain Interior Upland Longleaf Pine Woodland - Offsite Hardwood
- East Gulf Coastal Plain Interior Upland Longleaf Pine Woodland - Open Understory
- East Gulf Coastal Plain Large River Floodplain Forest - Forest Modifier
- East Gulf Coastal Plain Large River Floodplain Forest - Herbaceous Modifier
- East Gulf Coastal Plain Limestone Forest
- East Gulf Coastal Plain Maritime Forest
- East Gulf Coastal Plain Near-Coast Pine Flatwoods - Offsite Hardwood Modifier
- East Gulf Coastal Plain Near-Coast Pine Flatwoods - Open Understory Modifier
- East Gulf Coastal Plain Near-Coast Pine Flatwoods - Scrub/Shrub Understory
- East Gulf Coastal Plain Northern Dry Upland Hardwood Forest
- East Gulf Coastal Plain Northern Mesic Hardwood Forest
- East Gulf Coastal Plain Small Stream and River Floodplain Forest
- East Gulf Coastal Plain Southern Mesic Slope Forest
- Evergreen Plantations or Managed Pine (can include dense successional regrowth)

### 66 - Blue Ridge

- Appalachian Hemlock-Hardwood Forest
- Central and Southern Appalachian Montane Oak Forest
- Central and Southern Appalachian Northern Hardwood Forest
- Evergreen Plantations or Managed Pine
- South-Central Interior Small Stream and Riparian
- Southern and Central Appalachian Cove Forest
- Southern and Central Appalachian Oak Forest
- Southern and Central Appalachian Oak Forest - Xeric
- Southern Appalachian Low Mountain Pine Forest
- Southern Appalachian Montane Pine Forest and Woodland

### 67 - Ridge and Valley

- Allegheny-Cumberland Dry Oak Forest and Woodland - Hardwood
- Allegheny-Cumberland Dry Oak Forest and Woodland - Pine Modifier
- Evergreen Plantations or Managed Pine
- Northeastern Interior Dry Oak Forest - Mixed Modifier
- Northeastern Interior Dry Oak Forest - Virginia/Pitch Pine Modifier
- Northeastern Interior Dry Oak Forest-Hardwood Modifier
- South-Central Interior Mesophytic Forest
- South-Central Interior Small Stream and Riparian
- Southern and Central Appalachian Cove Forest
- Southern and Central Appalachian Oak Forest
- Southern Appalachian Low Mountain Pine Forest
- Southern Ridge and Valley Dry Calcareous Forest

### 68 - Southwestern Appalachians

- Allegheny-Cumberland Dry Oak Forest and Woodland - Hardwood
- Allegheny-Cumberland Dry Oak Forest and Woodland - Pine Modifier
- Appalachian Hemlock-Hardwood Forest
- Evergreen Plantations or Managed Pine
- South-Central Interior Mesophytic Forest
- South-Central Interior Small Stream and Riparian
- Southern Appalachian Low Mountain Pine Forest
- Southern Ridge and Valley Dry Calcareous Forest

### 69 - Central Appalachians

- Allegheny-Cumberland Dry Oak Forest and Woodland - Pine Modifier
- Appalachian Hemlock-Hardwood Forest
- Northeastern Interior Dry Oak Forest-Hardwood Modifier
- South-Central Interior Mesophytic Forest
- Southern and Central Appalachian Cove Forest
- Southern Appalachian Low Mountain Pine Forest
- Southern Appalachian Montane Pine Forest and Woodland

### 70 - Western Allegheny Plateau

- Allegheny-Cumberland Dry Oak Forest and Woodland - Pine Modifier
- Appalachian Hemlock-Hardwood Forest
- South-Central Interior Mesophytic Forest
- South-Central Interior Small Stream and Riparian
- Southern Appalachian Low Mountain Pine Forest
- Southern Ridge and Valley Dry Calcareous Forest

### 71 - Interior Plateau

- Northern Atlantic Coastal Plain Dry Hardwood Forest
- Evergreen Plantations or Managed Pine (can include dense successional regrowth)
- Nashville Basin Limestone Glade
- South-Central Interior Highlands Dry Oak Forest
- South-Central Interior Mesophytic Forest
- South-Central Interior Small Stream and Riparian

### 72 - Interior River Valley and Hills

- Northern Atlantic Coastal Plain Dry Hardwood Forest
- Evergreen Plantations or Managed Pine (
- South-Central Interior Highlands Dry Oak Forest
- South-Central Interior Large Floodplain - Forest Modifier
- South-Central Interior Mesophytic Forest
- South-Central Interior Small Stream and Riparian

### 73 - Mississippi Alluvial Plain

- East Gulf Coastal Plain Small Stream and River Floodplain Forest
- Mississippi River Low Floodplain (Bottomland) Forest
- Mississippi River Riparian Forest
- Open Water (Aquaculture)

### 74 - Mississippi Valley Loess Plains

- East Gulf Coastal Plain Interior Shortleaf Pine-Oak Forest - Hardwood
- East Gulf Coastal Plain Interior Shortleaf Pine-Oak Forest - Mixed
- East Gulf Coastal Plain Jackson Plain Dry Flatwoods - Open Understory
- East Gulf Coastal Plain Large River Floodplain Forest - Forest Modifier
- East Gulf Coastal Plain Northern Loess Bluff Forest
- East Gulf Coastal Plain Northern Loess Plain Oak-Hickory Upland - Hardwood
- East Gulf Coastal Plain Northern Loess Plain Oak-Hickory Upland - Juniper
- East Gulf Coastal Plain Northern Mesic Hardwood Forest
- East Gulf Coastal Plain Small Stream and River Floodplain Forest
- East Gulf Coastal Plain Southern Loess Bluff Forest
- East Gulf Coastal Plain Southern Mesic Slope Forest
- Evergreen Plantations or Managed Pine

### 75 - Southern Coastal Plain

- Atlantic Coastal Plain Blackwater Stream Floodplain Forest - Forest Modifier
- Atlantic Coastal Plain Central Salt and Brackish Tidal Marsh
- Atlantic Coastal Plain Longleaf Pine Woodland
- Atlantic Coastal Plain Small Blackwater River Floodplain Forest
- Atlantic Coastal Plain Small Brownwater River Floodplain Forest
- Atlantic Coastal Plain Southern Maritime Forest
- Atlantic Coastal Plain Southern Wet Pine Savanna and Flatwoods
- Central Florida Herbaceous Seep
- Central Florida Upland Longleaf Pine Island - Open Understory Modifier
- Deciduous Plantations
- East Gulf Coastal Plain Interior Upland Longleaf Pine Woodland - Open Understory
- East Gulf Coastal Plain Near-Coast Pine Flatwoods - Offsite Hardwood
- East Gulf Coastal Plain Near-Coast Pine Flatwoods - Open Understory
- Evergreen Plantations or Managed Pine
- Florida Dry Prairie
- Florida Peninsula Inland Scrub
- Floridian Highlands Freshwater Marsh
- South Florida Pine Flatwoods
- Southern Coastal Plain Blackwater River Floodplain Forest
- Southern Coastal Plain Hydric Hammock
- Southern Coastal Plain Nonriverine Basin Swamp
- Southern Coastal Plain Nonriverine Cypress Dome
- Southern Coastal Plain Oak Dome and Hammock

### 76 - Southern Florida Coastal Plain

- Deciduous Plantations
- South Florida Bayhead Swamp
- South Florida Cypress Dome
- South Florida Dwarf Cypress Savanna
- South Florida Everglades Sawgrass Marsh
- South Florida Freshwater Slough and Gator Hole
- South Florida Mangrove Swamp
- South Florida Pine Flatwoods
- South Florida Pine Rockland
- South Florida Wet Marl Prairie
- Southern Coastal Plain Hydric Hammock

**Figure 1.**—Continued

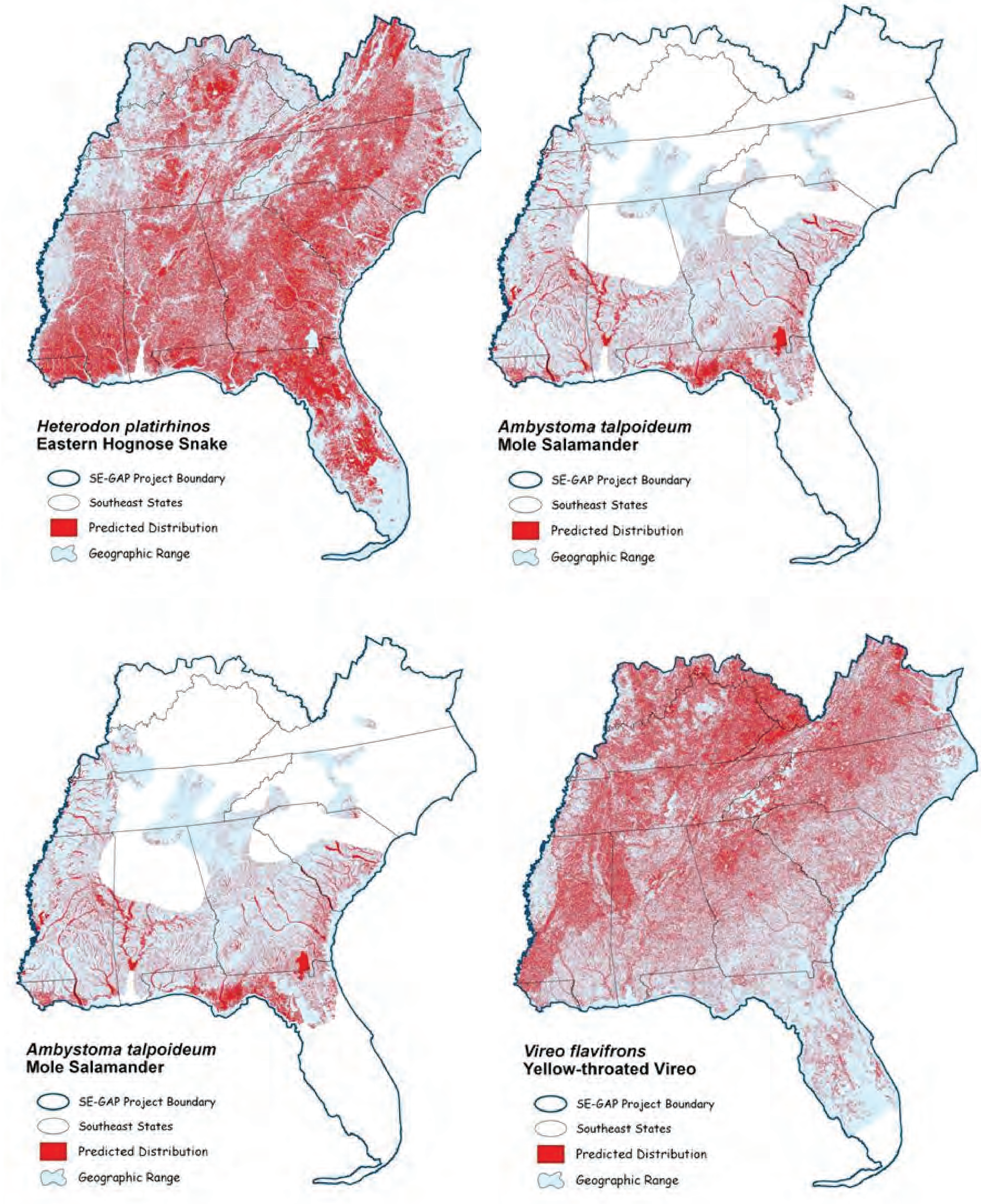



**Figure 2.** Examples of Southeast Regional Vertebrate Species Models.

Our goal for this project was to create a seamless database of the federal and state lands for nine states of the Southeast Region (AL, FL, GA, KY, MS, NC, SC, TN, and VA). This dataset, while a stand alone product, is designed to fit a national framework. Many lessons learned and advances made in the process of developing the Southwest Gap Stewardship mapping effort were incorporated directly in the development of this database.

## Methods

Database development started with a listing of all state and Federal land management agencies throughout the region. Each agency was then contacted and the most current digital boundary data and copies of the management plans were requested. Once the information was compiled, the land management status was assigned based on GAP's standard by following the dichotomous key to answer questions specific to the management on each parcel (Table 1). The spatial data were compiled and edited in an ArcGIS 9.1 Geodatabase format.

This was the first Gap level mapping effort for stewardship in the state of Alabama, so the Alabama Gap Project took the lead in compiling, attributing, and reviewing the stewardship data within the state. The remaining seven states were compiled and attributed at New Mexico State University. The final review of the regional dataset is being done at North Carolina State University.

## Preliminary Results

Information from more than 32 different state and Federal agencies and more than 40,000 parcels has been compiled for the nine southeastern states. At the regional level, 1.1 percent of the lands are categorized as status 1, 2.3 percent as status 2, and 6.4 percent as Status 3 (Figure 3, Table 1). Florida has the highest proportion of managed lands (25 percent, status 1, 2, and 3). Six states have less than 10 percent of their lands in management (Alabama, Georgia, Kentucky, Mississippi, South Carolina, and Tennessee). North Carolina and Virginia barely exceed the 10 percent threshold.

Status 1 and 2 lands, often considered sufficient for protecting a species or plant communities, make up 3.4 percent of the region. In rank order by area (km$^2$) Florida, Georgia, and Virginia have the most status 1 and 2 lands. Some of the larger status 1 areas include parts of the Marjory Stoneman Douglas Wilderness, Great Smoky Mountains National Park, Shenandoah National Park, Great Dismal Swamp National Wildlife Refuge, Everglades National Park, and the Shenandoah Wilderness.

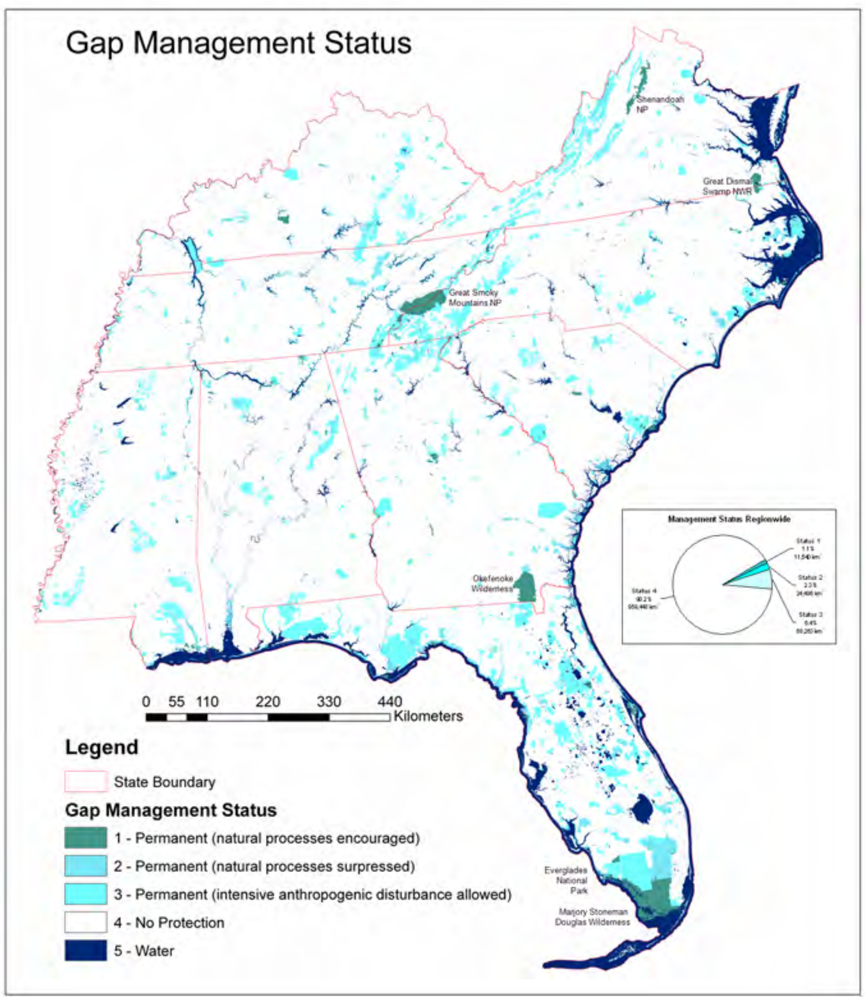



**Figure 3.** Southeast Regional Land Management Status.

**Table 1.** Land management by state, Southeast Gap Analysis.

[**Abbreviations:** km$^2$, square kilometer. Values are in square kilometers; values in parentheses are percentage of state. **Percentage of state:** water bodies greater than 40 hectares excluded from the calculations.]

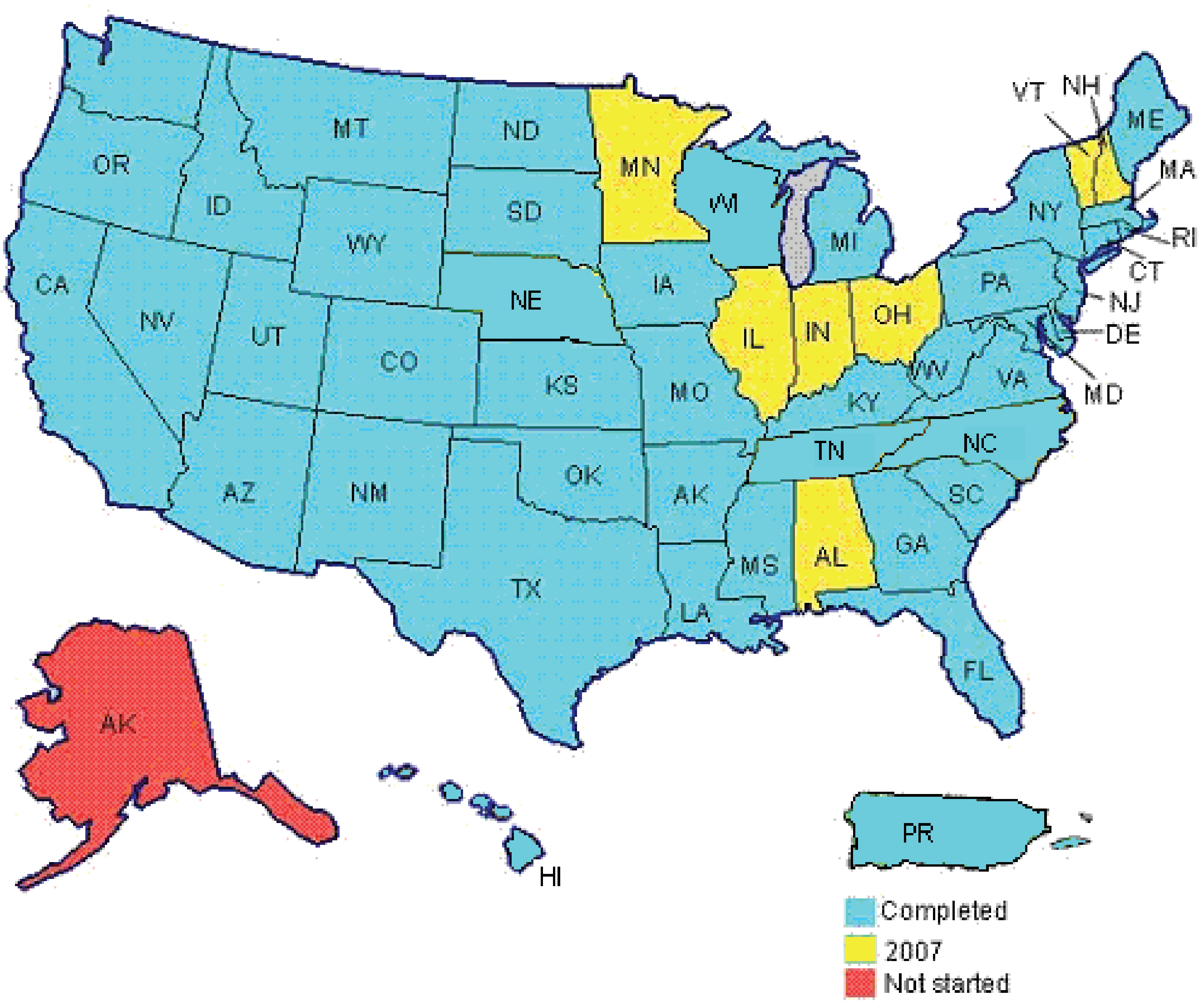
| | Status 1 | Status 2 | Status 3 | Status 4 | Total |
|---|---|---|---|---|---|
| Alabama | 295<br>(0.2) | 1,263<br>(1.0) | 3,874<br>(2.9) | 126,300<br>(95.9) | 131,732 |
| Florida | 4,723<br>(3.3) | 7,224<br>(5.1) | 24,037<br>(17) | 105,608<br>(74.6) | 141,592 |
| Georgia | 1,860<br>(1.2) | 3,224<br>(2.1) | 5,701<br>(3.8) | 140,062<br>(92.9) | 150,847 |
| Kentucky | 270<br>(0.3) | 1,352<br>(1.3) | 4,742<br>(4.6) | 96,549<br>(93.8) | 102,912 |
| Mississippi | 151<br>(0.1) | 1,567<br>(1.3) | 5,742<br>(4.7) | 114,178<br>(93.9) | 121,651 |
| North Carolina | 1,451<br>(1.1) | 2,525<br>(2.0) | 8,770<br>(6.9) | 113,854<br>(89.9) | 126,599 |
| South Carolina | 339<br>(0.4) | 1,512<br>(1.9) | 4,057<br>(5.2) | 72,437<br>(92.5) | 78,345 |
| Tennessee | 1,255<br>(1.2) | 2,573<br>(2.4) | 4,696<br>(4.4) | 98,503<br>(92.0) | 107,026 |
| Virginia | 1,197<br>(1.2) | 3,257<br>(3.2) | 6,631<br>(6.4) | 91,958<br>(89.2) | 103,043 |
| Regionwide | 11,541<br>(1.1) | 24,496<br>(2.3) | 68,268<br>(6.4) | 959,448<br>(90.2) | 1,063,748 |

## Reference Cited

Vogelman, J.E., S.M., Howard, L. Yang, C.R. Larsen, B.K. Wylie, and N. Van Direl. 2001. National Land Cover Database 2001 (NLCD). U.S. Department of Interior, USGS Earth Resources Observation Systems (EROS) Data Center.

# STATE PROJECT REPORTS

Status of State GAP Projects as of December 2007




All completed products and reports are available through the GAP web site at http://gapanalysis.nbii.gov. Draft data and other products may be obtained from the state project PI. Contact information for completed states can be found on the web site. Updates on incomplete projects are included below. Many completed projects are currently being remapped as part of regional projects. For information on regional projects, check the regional projects section of this Bulletin.

# Updates on Incomplete Projects

## Alabama

Near Completion
Anticipated completion date: December 2007

**Contact:**

James B. Grand, PI
Leader, Alabama Cooperative Fish and Wildlife Research Unit
Auburn University, Auburn
bgrand@acesag.auburn.edu, 334/844-4796

Amy L. Silvano, Coordinator
Alabama Cooperative Fish and Wildlife Research Unit
Auburn University, Auburn
silvaal@auburn.edu, 334/844-9295

**Land cover:** Complete.

**Animal modeling:** Complete.

**Land stewardship mapping:** Complete.

**Analysis:** Complete.

**Reporting and data distribution:** Draft land cover, animal distribution, and stewardship data will be available for download in early fall 2007 from the AL-GAP website (http://www.auburn.edu/gap). The final report is in progress, and we anticipate it will be submitted for peer-review in winter 2007.

**Papers and posters presented in 2006/2007**:

Kleiner, K.J. and M.D. MacKenzie. 2006. Mapping ecological systems in the East Gulf Coastal Plain via remote sensing: balancing interpretation and modeling. Paper presented at the Ecological Society of America (ESA) 91st Annual Meeting, Memphis, TN. August 7, 2006.

Kleiner, K. J. and M.D. MacKenzie. 2006. Mapping ecological systems in the East Gulf Coastal Plain via remote sensing: balancing interpretation and modeling. Paper presented at the Third Annual AL State GIS Symposium, Auburn, AL. November 1, 2006.

Kleiner, K.J., A. Vogt, M.D. MacKenzie, and J.B. Grand. 2007. Developing a decision-support tool for longleaf pine conservation the Southeast. 92nd Annual Meeting of the Ecological Society of America, San Jose, CA. August 9, 2007.

MacKenzie, M.D., K.J. Kleiner, J.S. Hogland, A.L. Silvano, and J. B. Grand. 2006. A map of the ecological systems of the East Gulf Coastal Plain based on satellite imagery. Poster presented at the Ecological Society of America (ESA) 91st Annual Meeting, Memphis, TN. August 7, 2006.

MacKenzie, M.D., K.J. Kleiner, J.S. Hogland, A.L. Silvano, and J. B. Grand. 2006. A map of the ecological systems of the East Gulf Coastal Plain based on satellite imagery. Poster presented at the Third Annual AL State GIS Symposium, Auburn, AL. November 1, 2006.

Silvano, A.L., K.J. Kleiner, M.D. MacKenzie, and J.B. Grand. 2006. Alabama Gap Analysis Project: Developing Geographical Data for Biodiversity Conservation and Management. Paper presented at the Third Annual AL State GIS Symposium, Auburn, AL. November 1, 2006.

## Alaska

Project under way.
Anticipated completion date: December 2010

**Land stewardship mapping**: Completed. Draft data available through GAP ftp site (ftp://ftp.gap.uidaho.edu).

## Illinois

Near Completion.
Anticipated completion date: December 2007

Review under way.

**Contact:**
Tari Tweddale
GAP Coordinator
Illinois Natural History Survey, Champaign
tweicher@uiuc.edu, 217/265-0583

**Land cover:** Complete.

**Animal modeling:** Complete.

**Land stewardship mapping:** Complete.

**Analysis:** Complete.

**Reporting and data distribution:** The IL-GAP team is now in the process of compiling the final report and completing the necessary revisions to the data deliverables.

## Indiana

Near completion.
Anticipated completion date: December 2007

Review under way.

**Contact:** Forest Clark
U.S. Fish and Wildlife Service
Bloomington, IN
forest_clark@fws.gov
812/334-4261 x206

**Land cover:** The Indiana Land Cover data are complete.

**Animal modeling:** The Indiana project completed the modeling of 300 vertebrate species.

**Land stewardship mapping:** The Land Stewardship map of Indiana, developed primarily under the aegis of the Indiana Department of Natural Resources, Division of Fish and Wildlife is complete.

**Analysis:** A gap analysis of Indiana has been run.

**Reporting and data distribution:** The final report has been completed and final revisions are being made. Project completion is expected in December 2007.

## Minnesota

Near completion.
Anticipated completion date: December 2007

Review under way.

**Contact:** Gary Drotts
Minnesota Department of Natural Resources, Brainerd
gary.drotts@dnr.state.mn.us, 218/828-2314

**Land cover:** Complete.

**Animal modeling:** Complete.

**Land stewardship mapping:** Complete.

**Analysis:** Complete.

**Reporting and data distribution:** The IL-GAP team is now in the process of compiling the final report and completing the necessary revisions to the data deliverables.

## Ohio

Near completion.
Anticipated completion date: September 2006

Review under way.

**Contacts:** Land cover, Dr. J. Raul Ramirez
The Ohio State University Center for Mapping, Columbus
raul@cfm.ohio-state.edu, 614/292-6557.

**Animal modeling:** Troy Wilson
U.S. Fish and Wildlife Service, Reynoldsburg
614-469-6923.

**Land cover:** Complete.

**Animal modeling:** Complete.

**Land stewardship mapping:** Complete.

**Analysis:** Complete.

**Reporting and data distribution:** The Ohio Terrestrial Gap analysis and final report will be completed by December 2007.

The *Gap Analysis Bulletin* is published annually by the USGS Biological Resources Discipline's Gap Analysis Program. The editors are Jill M. Maxwell, Kevin Gergely, Jocelyn Aycrigg, Anne Davidson, Gabrielle Canonico, and Nicole Coffey.

Suggested citation: Maxwell et al., editors. 2007. *Gap Analysis Bulletin* No. 15. http://gapanalysis.nbii.gov

| REPORT DOCUMENTATION PAGE | *Form Approved* *OMB No. 0704-0188* |
|---|---|

The public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.

**PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.**

| 1. REPORT DATE *(DD-MM-YYYY)* | 2. REPORT TYPE | 3. DATES COVERED *(From - To)* |
|---|---|---|
| 29-02-2008 | Information report | 01-01-2007 - 12-31-2007 |

**4. TITLE AND SUBTITLE**
Gap Analysis Bulletin

**5a. CONTRACT NUMBER**

**5b. GRANT NUMBER**

**5c. PROGRAM ELEMENT NUMBER**

**6. AUTHOR(S)**
Jill Maxwell, Kevin Gergely, Jocelyn Aycrigg, Gabrielle Canonico, Anne Davidson, and Nicole Coffey, editors

**5d. PROJECT NUMBER**

**5e. TASK NUMBER**

**5f. WORK UNIT NUMBER**

**7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)**
USGS/BRD/Gap Analysis Program
530 S. Asbury Street, Suite 1
Moscow, ID 83843

**8. PERFORMING ORGANIZATION REPORT NUMBER**
No. 15

**9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)**
U.S. Geological Survey
Biological Resources Division
Reston, VA 20192

**10. SPONSORING/MONITOR'S ACRONYM(S)**
USGS

**11. SPONSORING/MONITORING REPORT NUMBER**

**12. DISTRIBUTION/AVAILABILITY STATEMENT**
Copies of this publication are available from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161 (1-800-553-6847 or 703-487-4650). Copies are also available from the Defense Technical Information Center, Attn.: Help Desk, 8725 John J. Kingman Road, Suite 0944, Fort Belvoir, VA 22060-6218 (1-800-225-3842 or 703-767-9050)

**13. SUPPLEMENTARY NOTES**
Published annually

**14. ABSTRACT**
The 2007 issue of the Gap Analysis Bulletin is the fifteenth in a series of annual publications produced by the Gap Analysis Program. Gap Analysis Bulletin No. 15 features 11 articles on various aspects of gap analysis methods and results. Topics addressed include applications, land cover, and aquatic gap analysis. The Bulletin also includes a section on the current status of each GAP state project, regional project, and aquatic projects. This issue also contains summaries for completed GAP state projects.

**15. SUBJECT TERMS**
Biodiversity, conservation biology, Gap Analysis Program, animal modeling, aquatic GAP, land use planning, vegetation mapping

| 16. SECURITY CLASSIFICATION OF: a. REPORT | b. ABSTRACT | c. THIS PAGE | 17. LIMITATION OF ABSTRACT | 18. NUMBER OF PAGES | 19a. NAME OF RESPONSIBLE PERSON |
|---|---|---|---|---|---|
| U | U | U | SAR | 80 | Jill Maxwell |
| | | | | | 19b. TELEPHONE NUMBER *(Include area code)* 208-885-3550 |

Table of Contents continued:




USGS Gap Analysis Program
530 S. Asbury, Suite 1
Moscow, ID 83843


RETURN SERVICE REQUESTED


Printed on recycled paper