Freshwater gap analysis

Introduction to gap analysis

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Freshwater taxa are some of the most threatened components of biodiversity worldwide. This pattern is the result of extensive human impacts to lands and waters which sustain aquatic ecological processes, and inadequate inclusion of freshwater biodiversity in conservation planning and strategies. The primary challenges for identifying gaps in freshwater biodiversity protection are insufficient species occurrence and distribution data, lack of a method to describe and map patterns of freshwater ecosystem diversity, and a poor understanding of how conservation landscapes should be designed to accommodate the complex processes and connected nature of freshwater systems.

Given the general deficiency of freshwater species data and the urgency to move forward with biodiversity conservation, freshwater ecosystems have become primary conservation targets. Several methods, similar in approaches and outputs, have been developed independently to address the challenge of describing and mapping freshwater ecosystems. These approaches are flexible to meet the different levels of data availability worldwide. They all describe patterns of ecological processes and aquatic habitats within a larger biogeographic context. This biogeographic context can be provided by maps and descriptions of freshwater ecoregions that have been published for certain regions[1] and are drafted and will soon be made available for the rest of the world. Where they are not available, regional biogeography information should be used.

Within regions, information on freshwater biodiversity is inconsistent, but there is a wealth of information on the general relationships between freshwater biodiversity, ecological processes and physical habitat. The types and attributes of many significant ecological processes and physical habitats can be classified and mapped from readily available spatial data using a Geographic Information System (GIS). These data allow classification of freshwater ecosystems at varying spatial scales, permitting the description and delineation of patterns and interrelationships among lakes, streams and wetlands.

Spatial data that are generally used include:

- ✓ Hydrography (rivers and lakes)
- ✓ Digital Elevation Models (DEM)
- ✓ Geology
- ✓ Land cover
- ✓ Vegetation
- ✓ Climate

Other data that can be used if available include:

- ✓ Stream flow (gage station data)
- ✓ Lake depth
- ✓ Soils
- ✓ Physiography

These data are then used to generate ecological attributes of freshwater ecosystems. These attributes include:

- ✓ River/ lake size and density

- ✓ River gradient
- ✓ Lake depth, shoreline complexity
- ✓ River/ lake elevation
- ✓ River/ lake network position (e.g. headwaters, lower drainage)
- ✓ River/ lake connectivity (e.g. small streams connected to other small streams, connected to large rivers, connected to lakes, lakes isolated/connected to river systems)
- ✓ Water source and flow, temperature and chemistry regimes
- ✓ Stream and lake geomorphology

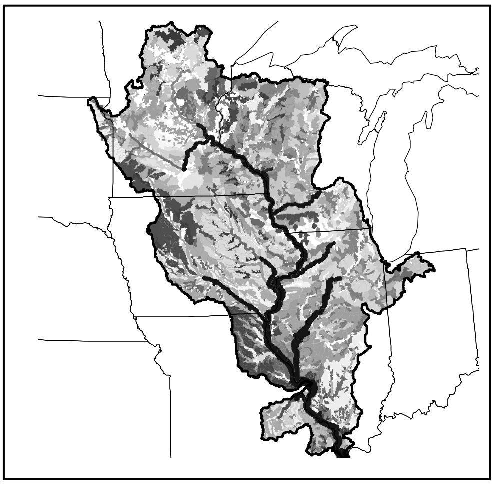

Figure 1: Freshwater Ecosystems map for the Upper Mississippi River freshwater ecoregion, United States[2]

Design of protected areas for conserving freshwater biodiversity

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Freshwater systems present a different set of challenges compared to terrestrial gap analysis and protected area design. Freshwaters are generally linear, connected hydrologically, and their position at the lowest point on the landscape means that they may be affected by any activities occurring within their catchments[3]. A protected area overlapping with a freshwater feature of interest (e.g. a rare species' habitat) will likely confer only partial protection to that feature unless the protected area encompasses the areas providing important ecological processes, such as the entire upstream catchment and perhaps even the downstream system as well. Conversely, a protected area situated in the catchment of a freshwater feature may provide some degree of protection to that feature, such as through regulation of downstream water quality and quantity, even though there may be no geographic overlap.

Identifying gaps in protection for particular freshwater species or habitat types, therefore, is not necessarily 100 per cent equivalent to identifying areas requiring protected area designation. Once gaps in protection for freshwater species and habitats are determined, the next step is ideally to identify the ecosystem processes critical to maintaining those features, the areas over which those processes operate, and the sources and scales of threats impinging on the processes. However, as the vast majority of freshwaters around the world are data-poor, we offer some possible short-cuts to assist in expedient freshwater protected area design.

First, perhaps the most important input to designing protected areas for freshwaters is a map of drainage basins (also known as watersheds and catchments). This map would preferably be in digital format and contain several layers of basins, from the largest (e.g. the Amazon) to much smaller ones (e.g. those of third or fourth-order tributary streams). In the past such maps were unavailable for large portions of the world, but soon they will be available globally at very high resolution, derived from new digital elevation data (for information and updates, see http://www.worldwildlife.org/science/freshwater.cfm). Such basin maps can be used to design protected areas that encompass, to the best extent possible, the areas draining to freshwater features of interest. Using basin boundaries as protected area boundaries has the added benefit of potentially reducing illegal incursions into protected areas via river systems[4].

Secondly, because most freshwaters systems are linear and connected, it is important to protect critical systems from fragmentation by dams, levees, and other longitudinal and lateral barriers (as well as to protect natural barriers from projects like interbasin water transfers). Designating entire freshwater systems from headwaters to mouth as off-limits to new barriers may be impossible, but key portions of those systems may be protected through designations that could simultaneously permit sustainable uses.

Design of protected areas to conserve freshwater biodiversity is a new field with ideas evolving rapidly[5]. In addition to the two suggestions provided above, we recommend consulting with freshwater ecologists and conservation biologists to design the most effective and efficient protected area network within time, data, and resource constraints.

Tools for freshwater gap analysis

Documents and Tools for Focusing Freshwater Efforts Across Large Geographic Areas):
http://www.freshwaters.org/info/large/documents.shtml#gis

- ✓ Links to tools, methods, case studies of applying freshwater ecosystems in regional conservation planning, and other resources

A freshwater classification Approach for Biodiversity Conservation Planning.
Higgins et al. 2005. *Conservation Biology* 19(2): 432-445. http://www.blackwell-synergy.com/servlet/useragent?func=callWizard&wizardKey=salesAgent:1115913466769&action=show

Guide to freshwater conservation
Silk, N. and K. Ciruna, (Eds). 2004. **A Practitioner's Guide to Freshwater Biodiversity Conservation.** The Nature Conservancy. Arlington, VA. http://www.freshwaters.org/pub/

GIS tools for freshwater biodiversity conservation planning
T W Fitzhugh, 2005, *Transactions in GIS* **9**(2); 247-263. http://www.blackwell-synergy.com/links/doi/10.1111/j.1467-9671.2005.00215.x/abs/

Multi-scale river environment classification for water resources management
T H Snelder and B J F Biggs, 2002, *Journal of the American Water Resources Association,* **38**: 1225-1240. http://www.awra.org/cgi-bin/sc_jawra_reprints.cgi?view_article&630345858&01251

Case studies for freshwater conservation planning and gap assessment.

- ✓ **Australia**: Kingsford R T, H Dunn D Love J Nevill J Stein and J Tait (2005); *Protecting Australia's rivers, wetlands and estuaries of high conservation value: a blueprint*; Land and Water Australia; Canberra. http://www.ids.org.au/~cnevill/freshwater.htm.
- ✓ **Australia**: Nevill, J, and N Phillips, (eds.) (2004); *The Australian Freshwater Protected Area Resource Book: the policy background, role, and importance of protected areas for Australian inland aquatic ecosystems*, Australian Society for Limnology. http://www.users.bigpond.com/jon.nevill/FW_ProtectedArea_SourceBook.doc
- ✓ **Australia**: Nevill, J (2002); Representative freshwater aquatic protected areas: the Australian context, Paper presented to the First World Congress on Aquatic Protected Areas, Cairns

Australia, August 14-17 2002. Revised 20/11/03, http://www.ids.org.au/~cnevill/ASL_State_fw_APA_summary.doc

- ✓ **Brazil**: Bryer, M T et al. (2004); *Classificacao dos Ecossistemas Aquaticos do Pantanal e da Bacia do Alto Paraguai*, The Nature Conservancy, Brazilia, Brazil.

- ✓ **South Africa**: Roux et al. (2002); Use of landscape – level river signatures in conservation planning: a South African case study, *Conservation Ecology* **6**(2): 6. http://www.ecologyandsociety.org/vol6/iss2/art6/

- ✓ **South Africa**: Nel, J et al. (2004); South African National Spatial Biodiversity Assessment, Technical Report: Volume II. River Component, CSIR-Environment. Department of water affairs and forestry, Botanical Society of South Africa. CSIR Report Number ENV-S-I-2004-063. http://www.sanbi.org/frames/nsbafram.htm

- ✓ **US – Missouri**: Sowa, S P, et al. (2005); *The aquatic component of gap analysis: the Missouri prototype*, Missouri Resource Assessment Partnership, University of Missouri, Columbia, Missouri. http://www.cerc.usgs.gov/morap/projects/aquatic_gap/sowa_etal_dod_legacy_final_report.pdf

- ✓ **US – Upper Mississippi**: Weitzell, R E, M L Khoury, P Ganon, B Scherers, D Grossman, and J Higgins (2003); *Conservation Priorities for freshwater biodiversity in the Upper Mississippi River Basin*, Natureserve and The Nature Conservancy: http://www.natureserve.org/aboutUs/upperMississippi.jsp

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[1] See for instance Abel et al (2000) op cit and Theime et al (2005) op cit

[2] Weitzell, R E, M L Khoury, P Ganon, B Scherers, D Grossman, and J Higgins (2003); *Conservation Priorities for freshwater biodiversity in the Upper Mississippi River Basin*, Natureserve and The Nature Conservancy: http://www.natureserve.org/aboutUs/upperMississippi.jsp

[3] Abell, R, M Thieme, E Dinerstein, and D Olson. (2002); *A sourcebook for conducting biological assessments and biodiversity visions for ecoregion conservation. Volume II: Freshwater ecoregions*, World Wildlife Fund, Washington, DC, USA

[4] Peres, C A and J W Terborgh. (1995); Amazonian nature reserves: An analysis of the defensibility status of existing conservation units and design criteria for the future, *Conservation Biology* **9**:34-46

[5] Saunders, D L, J J Meeuwig, and A C J Vincent (2002); Freshwater protected areas: Strategies for conservation, *Conservation Biology* **16**:30-41