Freshwater Resources and Associated Terrestrial Landscapes

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2.1 Introduction

Most of the world's amphibian species exhibit a complex life history, with aquatic egg and larval stages followed by a rapid metamorphosis to a terrestrial adult stage. Some amphibian species are completely aquatic, with eggs, larval, and adult stages taking place either in the same water system (rivers, lakes) or in associated water systems (with short migrations overland). Still other amphibian species forgo the larval stage altogether and complete their life cycle on land, in terrestrial ecosystems. Most people associate amphibians with freshwater habitats, particularly ponds, and most active conservation efforts are aimed at the protection of such habitats. For most species that use freshwater habitats only to breed, the time they and their larvae spend in water represents only a small proportion of their life history. On land, amphibians are secretive and widely dispersed and relatively little is known about their natural history in terrestrial habitats. As a result, techniques to conserve amphibians in terrestrial habitats are poorly developed.

A number of recent studies that have compared the ecology of species that have declined dramatically with those that have not, have identified high altitude as a significant 'risk factor' for amphibians (Declining Amphibian Database; Hero and Morrison 2004; Lips *et al.* 2003). This effect is rather surprising, because upland habitats are generally not as affected by habitat change (e.g., agriculture) as lowland habitats, and for many of the declines that occur at higher altitudes, the immediate cause is not obvious.

It follows that if amphibians are to persevere, it is critical, not only that high quality aquatic ecosystems persist, but also that associated terrestrial habitat is protected. The degradation of either ecosystem type derails amphibian life cycles and affected populations become compromised, perhaps extirpated. It is particularly important that upland habitats, aquatic and terrestrial, be protected.

A majority of the world's 5,883 species (AmphibiaWeb, 9 Sept., '05) are found in tropical and low temperate ecosystems (see Fig. 1 and discussion below). Within these regions, direct developing (terrestrial) amphibians can be found almost anywhere on land except at very high altitudes. Amphibians with complex life histories are typically found within the vicinity of sources of freshwater that can be used for breeding. While several studies have attempted to document the distance adult amphibians move from their breeding sites, David Green (pers. comm.) has observed that the maximum distance noted by these studies is correlated with the geographic scope of the study. Our knowledge of the dispersal of amphibians across land is very poor and requires major research input, not least because understanding this aspect of amphibian ecology is vital for effective conservation.

2.2 Ecosystems

Aquatic ecosystems used by amphibians are typically freshwater, although some species breed in brackish water. Lentic freshwater ecosystems that support amphibians range from seasonal wetlands, through semi-permanent and permanent wetlands, to lakes and ponds. Lotic freshwater ecosystems that support amphibians range from seeps and springs, through small and large streams, to rivers. As a general rule, fishes exclude amphibians, therefore ecosystems with fewer fishes provide habitat for more amphibian species: seasonal wetlands support more species than lakes; seeps and springs support more species than rivers. Upland ecosystems are not only important to amphibians by providing habitats, but also human activities at higher watershed levels affect both terrestrial and aquatic habitat quality at lower levels.

2.3 Facts About Freshwater (Lean and Hinrichsen 1992; AAAS 2000)

- Less than 3% of the earth's surface is composed of freshwater.
- More than 75% of this is locked up (although likely not for long) as polar ice.
- 98% of the remaining freshwater lies underground.
- Therefore, only about 0.01% of the world's total freshwater is readily available to terrestrial life.
- Freshwater is unevenly distributed throughout the world, e.g., Canada has 30 times as much freshwater available to each of its citizens as China
- Freshwater is being contaminated by saltwater influxes, human waste and other byproducts of human use (e.g., endocrine disruptors, acid rain), as well as agricultural fertilizers and pesticides.
- Since 1950, the number of people on earth has increased from 2.5 to 6.5 billion, and the per capita use of freshwater has tripled.
- More than 60% of all freshwater used in the world is diverted for irrigating crops.

2.4 Facts About Upland Habitat (Lean and Hinrichsen 1992; AAAS 2000)

- Forests are the planet's largest reservoir of biological diversity, containing an estimated half of all the world's plant and animal species.
- Only about 50% (750 million out of 1.5 billion hectares) of historic mature tropical forests still stand.
- Tropical deforestation is increasing and is currently between 16.4 and 20.4 million hectares/yr.
- Temperate deforestation has been extensive (i.e., only 1.5% of Britain's original forest remains; Poland's Bialoweiza National Park contains the last major ancient forest in Central Europe).
- Logged temperate forests are often replanted as single-species plantations.
- Since the 1970s, large tracts of temperate forests have died.
- Grasslands have great biological value, being the original home of wheat, barley, millet and sorghum, but soils grow slowly and salts tend to build up.
- Since 1700, 560 million hectares of grassland and pasture have been converted to agricultural usage (Ramankutty and Foley 1999).
- Desertification of grassland and pasture threatens about 33% of the world's land surface.

2.5 How Does this Relate to Amphibians?

Amphibians are not distributed uniformly across the surface of the earth (Fig. 1). Except for the few species that live in brackish waters, amphibians occur exclusively in terrestrial or freshwater ecosystems. For any given longitude, species richness is higher near the equator, and lower towards the poles. The highest amphibian richness values occur in the tropical rainforests and moist tropical forests of Central America, South America, Equatorial Africa, and Eastern and Southeastern Asia. Developed regions such as North America, Europe, and Australia tend to have considerably fewer species.

Threats to amphibians involve alterations to both freshwater and terrestrial habitats. Rates of conversion of native vegetation to agriculture have been increasing (Fig. 2), including percent change in agricultural production (Fig. 2A), cropland area (Fig. 2B), and amount of permanent cropland (Fig. 2C).

There has been an increase in the area of land that is irrigated (Fig. 3). We noted previously that over 60% of the freshwater used by humans is water diverted for irrigation.

Forest cover is decreasing globally. These changes include decreases in natural forests (includes closed forests and open forests with at least 10% tree cover; Fig. 4A), decreases in closed canopy forest (Fig. 4b), and decreases in all forest types (natural, managed, etc.; Fig. 4C.).

Figure 5 indicates locations of larger wetlands worldwide, and Figure 6 shows wetlands of international importance, as recognized through the Ramsar Convention agreement (Navid, 1989). Tropical ecoregions, which provide important habitat for a rich diversity of amphibian fauna, are not well represented in the distribution of Ramsar wetlands. Nor are the very numerous ponds and other small freshwater habitats that exist on Earth; despite their small size, such habitats support a high diversity of plants and animals, including amphibians.

Composite rates of population-, agriculture-, and forest-related habitat change are indicated in Figure 7. This map shows the relative magnitude of the rates at which the landscape is being altered in ways that are likely to be detrimental to amphibian habitat. When this composite map of landscape change is compared with the map of amphibian richness (Fig. 8), a disturbing pattern emerges. Throughout much of the world, particularly Central America, northern and eastern South America, western sub-Saharan Africa, Madagascar, eastern India, Southeast Asia, and southern coastal regions of Australia, changes in land cover and land management correspond in an alarming way with regions of high amphibian richness.

2.6 The Conservation And Restoration Of Freshwater and Upland Systems Important to Amphibian Populations

Amphibians are often said to be "canaries in the coal mine" or sensitive indicators of environmental health. The implication here is that ecosystems have been compromised and amphibian populations are telling us this. The reverse, however, is also true. Diseases, such as chytrid fungus, target amphibians that occupy otherwise healthy ecosystems, and this loss of amphibians compromises ecosystems. Attempts to reverse amphibian declines must take both of these factors into account.

The first step towards reversing amphibian declines is to provide the high quality aquatic and terrestrial habitats that amphibians require. In some places these habitats exist, in others they once did but do not anymore. At least some of these latter areas should be the targets of restoration efforts, especially where associated amphibian species are in decline. The good news here is that these ecosystem restoration efforts will be required even in the absence of any primary consideration of amphibians. While oil is perceived to be the current limiting resource, in the future freshwater is likely to be the world's limiting resource. Policies promoting clean freshwater and the protection of sources of clean water through watershed management will undoubtedly benefit remaining amphibian populations.

American actor/comedian W. C. Fields (1940) is reputed to have said that he did not drink water because fish make love in it. He missed the point. If fish, and amphibians, can breed successfully in freshwater, it assures us that it is fit for us to drink.

2.7 Amphibians, Genetics and Landscapes

While our knowledge concerning the terrestrial lives of amphibians is deficient in many ways, we do know that some species can move considerable distances on land and colonize newly created aquatic breeding habitats very quickly. However, they can only do this from existing, established populations and so, if conservation efforts are to be effective, we need to improve knowledge about the movement of amphibians between breeding sites. Dispersal is a key consideration in metapopulation models of amphibians, which emphasize the importance of maintaining networks of breeding sites connected by suitable terrestrial habitat. A number of recent studies have looked at metapopulations within landscapes to determine the effects of geographical distance and habitat type on amphibian dispersal between breeding sites (Lannoo 1998; Semlitsch 1998, 2000). Such studies are most revealing when combined with genetic analyses which determine the 'genetic distance' between sites, that is, how isolated genetically adjacent sites are from one another. It is important that future studies of the relationship between amphibian abundance and terrestrial habitat are informed by the findings from the relatively new disciplines of landscape genetics and conservation genetics.

A study of the European frog *Rana latastei* (Garner *et al.* 2003) has looked at the genetic consequences of breeding site isolation, comparing ponds at the edge of the species' range, with those near the middle. Outlying, more isolated ponds show lower genetic variation. Significantly, animals from such ponds were more susceptible to infectious disease than animals from the core of the range. There is thus a further link that must be maintained, between landscape genetics and infectious disease.

2.8 Habitat Change

Many amphibian habitats are not stable over time, being subject to long-term changes, two of which are of particular importance in the conservation of amphibians: climate change, and ecological succession. Climate change alters temperature and rainfall patterns and thus has huge potential to negatively affect amphibian populations (See Chapter 3). A number of studies have already shown that amphibians are breeding earlier in the year than they were 20 years ago; whether this is beneficial or harmful to their long-term survival is not yet clear. An important implication of climate change is that habitat that is optimal for a particular species may move laterally across the landscape (e.g., many wild plants in the UK have shifted their ranges northwards) or, as in the case of montane habitats such as that at Monteverde, Costa Rica, shrink and eventually disappear altogether. It is important therefore that workers interested in landscape aspects of amphibian conservation maintain close contact with those working on climate change.

Many amphibian breeding habitats are subject to ecological succession. Permanent ponds are typically not permanent, but, if left unaltered, become overgrown and eventually fill in. The active conservation of amphibians will require a great deal of work, much of it experimental, to determine the best ways to manage amphibian habitats over long-periods to offset the effects of succession.

2.9 Actions

We must identify and outline steps to protect critical aquatic and terrestrial amphibian habitat. We identify three primary spatial scales on which to work: 1) continental/ecoregion, 2) watershed (focus), and 3) site levels, as well as the temporal scale, which must be addressed in order to preserve natural successional processes or to restore successional processes in areas that have been altered. Landscape issues should identify and protect the integrity of ecosystems at each of these spatial and temporal scales.

Specific priorities, threats and actions will need to be addressed with respect to the following life history variations: 1) species with a complex life history; 2) fully aquatic species; and 3) species with terrestrial development.

Specific actions to stem the decline of amphibians must directly include:

2.9.1 Securing existing habitat

a. Research: Identify key habitat requirements (aquatic & terrestrial) (budgetted in the KBA chapter).
b. Education: Develop and implement curriculum for primary throughsecondary/high school students; outreach program for general public ($100K per ecoregion per year x 40 ecoregions = $4 million per year).
c. Policy: Develop educational outreach program for policy makers ($3 million per year).
d. Management: Provide habitat management guidelines for amphibian habitat to land managers and land owners ($50K per ecoregion per year x 40 ecoregions = $2 million per year).

2.9.2 Preventing future habitat loss (water use/looking ahead)

e. Research: Quantify effects of anthropogenic perturbations on amphibian populations ($200K per ecoregion per year x 40 ecoregions = $8 million per year).
f. Education: Develop and implement curriculum for primary throughsecondary/high school students and outreach program for general public on how individual behaviors can be modified to improve watershed health (included in 1b).
g. Policy: Educate policy makers on impacts of industry, land use, and agriculture on local watershed health, and long-term consequences for human health and local economies (included in 1c).
h. Management: Provide habitat management guidelines to minimize future habitat loss for land managers and land owners (included in 1d).
i. Research: Identify restoration methods that improve amphibian habitat and population size (adaptive management) ($100K per ecoregion per year x 40 ecoregions = $4 million per year).

2.9.3 Restoring disturbed or compromised habitats

j. Education: Develop and implement educational curriculum to the public to demonstrate value of habitat restoration and healthy amphibian communities (included in 1b).
k. Policy: Educate policy makers on the value of amphibian habitat restoration to human and ecosystem health (included in 1c).
l. Management: Collaborate with land managers and property owners to develop effective restoration practices ($100K per ecoregion per year x 40 ecoregions = $4 million per year).

2.10 Budget

Total Annual Budget = $25 million per year

Total 5-year Budget = $125 million

2.11 List of Figures

(*Editors Note:* Figures accompanying this chapter may found in the online version of ACAP: www.amphibians.org)

Figure 1. Amphibian species richness. The map legend depicts classes of species richness, where each successive class represents twice the number of species as the previous class. Because of large differences in the availability of amphibian distribution information from around the world, species richness may be over-represented in some areas, and under-represented in others (from Gallant *et al., submitted*).

Figure 2. Agricultural changes from 1961 through 1998. A) Percent change in agriculture production. Many parts of the world experienced increased production, but nearly all of the ecoregions in southern Africa had decreased levels of production. Patterns of increase often followed ecoregion boundaries within continents, but similar ecoregion types across continents had different characteristics of change. B) Changes in agricultural production sometimes contrasted with patterns of change in cropland area. C) Amount of permanent cropland (i.e., land supporting crops that persist after harvest, such as orchards and plantations) increased throughout most of the world's agricultural areas.

Figure 3. Changes in forest cover from 1990 to 1995. A) Percent change in natural forests (includes closed forests and open forests with at least 10% tree cover). B) Changes in closed canopy forest shown as a percent of original closed forest cover. C) Percent change for all forest types (natural, managed, etc.).

Figure 4. Percent change in irrigated lands between 1961 and 1998.

Figure 5. Wetland distribution worldwide as recognized by the US Soil and Water Conservation Service Natural Resources Conservation Service, compiled by FAO-UNESCO.

Figure 6. Locations of wetlands of international importance, as recognized through the Ramsar Convention agreement. Tropical ecoregions, which provide important habitat for a rich diversity of amphibian fauna, are not well represented in the distribution of Ramsar wetlands.

Figure 7. Composited rates of population-, agricultural-, and forest-related change. The resulting patterns show the relative magnitude of the rates at which the landscape is being altered in ways that are likely detrimental to amphibian habitat. The specific maps used to derive the composite map included those showing changes in: human population from 1995–2000, cropland area, fertilizer application rates, irrigated acreage, closed canopy forest, and loss of tree species. Excluded were the maps of agricultural production (changes in production rates do not equate with areal changes in agricultural lands), permanent cropland (it includes only a subset of crop types), natural forests (data were unavailable for many countries), and total forest (it comprises everything from degraded forests, to plantations, to intact, relatively natural forests; from Gallant *et al.* (*submitted*).

Figure 8. Composited rates of landscape change compared with global amphibian distribution patterns (from Gallant *Et al., submitted*).