A Paradigm Shift in Wetland Boundaries

The decisions of a delineator in the field often mean the difference between a shopping center and a protected area or a parking lot and a nature preserve. Policy defines these stark consequences and the all-or-nothing choices delineators face. The author argues, however, that the idea of wetland boundaries that prevails in national wetland policy is too narrow.

BY RAYMOND D. SEMLITSCH

Many scientists approach wetland delineation as if wetlands exist as independent entities in the landscape rather than as parts of ecosystems that include upland habitat. This myopia is not a new problem; rather, it surfaced a number of years ago and was detailed recently by Meyer and co-authors (2003) and Gibbons (2003). I still attend meetings every year where scientists, managers, and regulators ignore obvious ecological connections and continue discussing wetlands as if they are islands amidst seemingly invisible surroundings. In fact, this pervasive view very likely influenced the U.S. Supreme Court's decision in *Solid Waste Agency of Northern Cook County v. U.S. Army Corps of Engineers*, when the notion of wetlands as "isolated" physical entities rather than functionally connected systems apparently prevailed.

While delineating and protecting a physical location or single habitat (i.e., a wetland) is certainly simpler than delineating and protecting the less-discrete and arguably more complex active processes that support such sites, scientific knowledge indicates that those processes, called ecosystem functions, are critical to maintaining healthy aquatic systems and the benefits we derive from them. The idea that protecting a wetland, lake, or stream requires protecting the active processes associated with the resource—processes that may cross physical and conceptual boundaries—is not really a new one. After all, the primary objective of the Clean Water Act is "to restore and maintain the chemical, physical, and biological integrity of the nation's waters" and to promote "basic research into the structure and function of freshwater aquatic ecosystems" so as "to improve understanding of the ecological characteristics necessary to the maintenance of the chemical, physical, and biological integrity of freshwater ecosystems." As this text shows, in 1972 legislators recognized that healthy water resources depend on healthy, functional aquatic ecosystems. Unfortunately, in the intervening decades, scientists and regulators seem to have forgotten this relationship, at least when delineating wetlands.

Courtesy of E. Harper

Spotted salamander, Ambystoma maculatum*, in Warren County, Missouri.*

I contend that to maintain healthy aquatic resources, we need to protect ecosystem functions. Doing so requires extending regulatory protection to the terrestrial habitats that surround wetlands. Aquatic and terrestrial habitats must be protected as single functional units, not as separate pieces. Traditional wetland boundaries should be viewed as starting points for protection and not as end points.

Understanding wetland protection in this way would be a paradigm shift in how we measure wetland boundaries, what those boundaries represent, and how they are involved in conservation. Here, I show why ecological processes, rather than easy-to-measure but ecologically incomplete human constructs, should determine wetland boundaries. I use amphibians as an example taxon because of their heavy dependence on wetlands, but similar arguments could be made using other taxa such as insects, reptiles, birds, and mammals.

The Nature of Boundaries

A boundary can be defined ecologically by its structure and function (Puth and Wilson 2001). "Structure" refers to physical forms such as trees at a forest-field edge or the shoreline at a wetland-upland edge. "Function" encompasses the ability of a boundary to regulate (e.g., slow, redirect, or stop) the movement of organisms, energy, or matter

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between habitats (Puth and Wilson 2001). The permeability of boundaries depends on the organism. For example, forest edges might allow the passage of some bird species but not others. Certain terrestrial mammals might approach a stream but avoid entering the water, while others might easily cross from bank to bank.

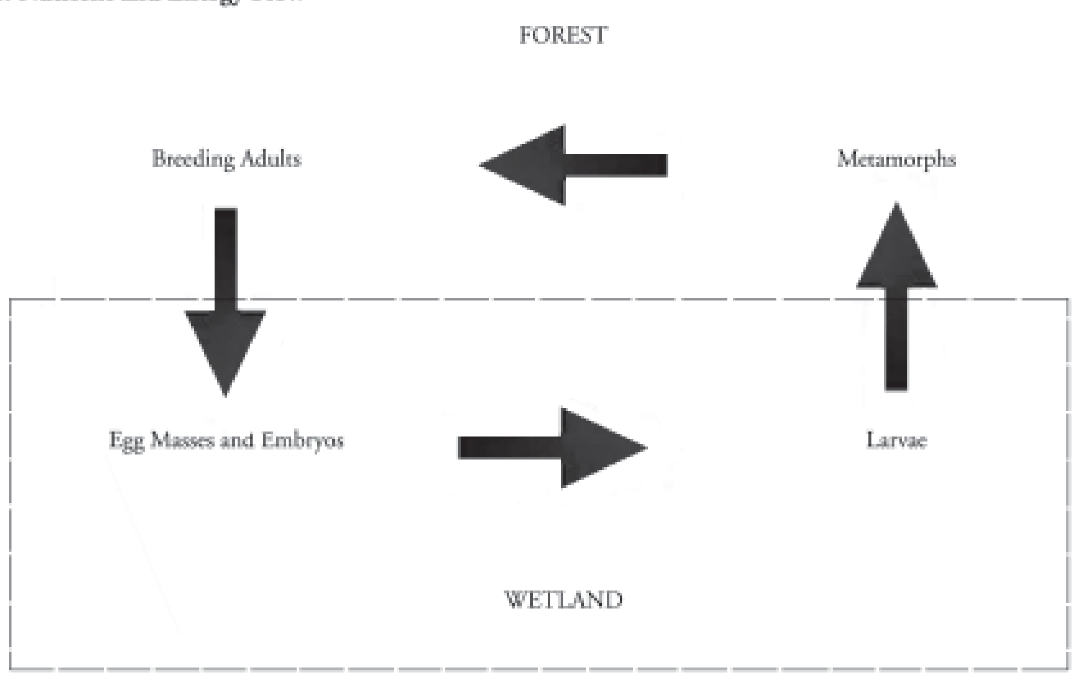
Most amphibians, along with many turtles and snakes, are semi-aquatic vertebrates that readily move across wetland boundaries during breeding or nesting migrations and disperse after metamorphosis or in response to droughts. For amphibians, conventional wetland boundaries are neither barriers nor redirectors of movement. In fact, wetlands and adjacent terrestrial ecosystems facilitate amphibian movement by providing a gradient of habitats, from wet to dry, that amphibians can use during different life-history stages (i.e., from aquatic larva to terrestrial juvenile phases). For organisms that have semi-aquatic life cycles and rely on aquatic and terrestrial habitats, boundaries between wetlands and uplands are not barriers at all.

The flow of matter or energy between terrestrial and aquatic habitats also suggests that wetland boundaries are not static. For example, during rains, organic matter and detritus move downhill from upland forests into wetlands via runoff, and leaves directly enter wetlands from the surrounding forest canopy. These "allochthonous" (extrinsic) resources can have large effects on the productivity of receiving wetlands.

Other materials are actively transported across gradients by animals. Amphibians with complex life cycles can act as vectors for energy flow across wetland boundaries, connecting freshwater and terrestrial ecosystems (see Figure 1, from Regester et al. 2006). During the breeding season, salamanders travel between 117 and 218 meters from upland terrestrial habitats to wetlands to mate and deposit eggs (Semlitsch and Bodie 2003). The eggs hatch and the remaining jelly coat decomposes. The free-swimming amphibian larvae feed on zooplankton and aquatic insects and rapidly grow until metamorphosis. However, not all eggs or larvae survive; typically less than 5 percent of hatchlings actually metamorphose (Semlitsch 2003). Those that do not survive are available to organisms at other trophic levels in the aquatic ecosystem, including decomposers and secondary consumers like dragonflies and birds.

When metamorphs leave wetlands, they bring aquatically derived nutrients and energy to terrestrial habitats. Of the metamorphs that leave ponds, only about 25 percent survive to reproduce in the same pond; others disperse to new wetlands or die, releasing nutrients and energy to the terrestrial food web. Regester and co-authors (2006) found that energy flow from salamanders into ponds was small relative to energy flow out of ponds. Gibbons and co-authors (2006) measured more than a ton (1,490 kilograms) of amphibian metamorph biomass leaving one 10-hectare wetland during a single year. Amphibians provide a key pond-to-forest subsidy by acting as vectors for the transport of nutrients and energy across wetland boundaries.

Figure 1. Nutrient and Energy Flow



A diagram of energy and nutrient flow (indicated by arrows) between forest and aquatic habitats using pond-breeding amphibians as an example. Diagram modified from Regester and co-authors (2006).

Boundaries Redefined

In other words, wetland boundaries as we have traditionally viewed them are not boundaries at all. A delineated wetland boundary neither stops nor redirects the flow of materials and energy between habitats. Rather, it facilitates such transfers. A human-conceived boundary is simply one part of a gradient of natural change in elevation, soil type, moisture, and vegetation. If our goal is to protect aquatic resources and the functional integrity of wetland ecosystems, we need to think about these gradients. We must think beyond static wetland boundaries and consider upland habitats where essential materials and energy destined for wetlands originate. We must identify the distances within which energy subsidies occur. Then, we can define areas that encompass ecosystem processes by measuring how far wetland-dependent organisms move and the extent to which their core habitats and activities extend beyond wetlands (sensu Semlitsch and Bodie 2003).

This new view of wetland boundaries would critically affect our definition of threats to wetlands. It would significantly alter, for example, our understanding of the full consequences of toxic pollutants absorbed or eaten by semi-aquatic species. Currently, ecotoxicologists focus on the transfer of contaminants within aquatic food webs. However, the new perspective on wetland boundaries outlined here would reveal that animal vectors transfer toxic pollutants to areas well beyond traditional wetland limits, thereby contaminating terrestrial habitats. Clearly, a paradigm of wetland protection that encompasses ecosystem functions and adjacent habitats can more effectively direct restoration and conservation efforts than an approach based simply on delineation of plants and soils. Wetlands are not truly protected when surrounding habitats and the processes that link the two areas are threatened. ■

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Courtesy of R. Semlitsch

A red eft, Notophthalmus viridescens*, in New Hampshire.*