Natural Restoration Basics for Wetlands

Around the world, dams, diversions, and drainage systems reengineer rivers for navigation, farming, and urban development, and this has caused vast changes in the environmental conditions of the flood plains adjacent to these rivers (Middleton, 2002). Even though "flood pulses," the periodic overflow of these rivers, were once the most important hydrological factor regulating all functions of the flood plain (Junk and others, 1986), now they have been reduced or eliminated along many of the world's waterways (Sparks and others, 1998). These changes in river channels have created a hydrologic setting on flood plains that has not been conducive to restoration and nature conservation (Middleton, 2002). Consequently, USGS scientists are studying the long-term effects of hydrologic changes on flood plains, such as how the restoration of baldcypress (*Taxodium distichum*) swamps has been hindered because seeds cannot disperse or germinate without the seasonally driven high and low water levels associated with the flood pulse.

Natural Regeneration and the Hydrology of Restored Wetlands

Millennia before the first restorationists began planting efforts to restore wetlands, vegetation could easily restore itself in small openings created by natural disturbances (for example windthrow, fire, flooding, or animals). In recent times, humans have changed the landscape so completely that natural regeneration can no longer occur in some cases (fig. 1). The reengineering of rivers may completely cut off flood-plain and tidal wetlands from flood pulsing and consequently impede the movement of seeds of plants and disseminules of other organisms. In addition, the fragmentation from development isolates natural forests and increases the distance that seeds must travel to restoration sites (Middleton, 1999).

The lack of flood pulsing undermines restoration in reengineered landscapes and also affects natural ecosystems on otherwise pristine floodplains. For instance, some forest composition has shifted from hydric (wet) to mesic (dry) species because of downcutting (stream cuts more deeply into channel) in rivers and lessening of flood pulsing across flood plains (Ouchley and others, 2000). In the U.S. Midwest, major floods no longer connect sedge meadows of the "Prairie Pothole Region," and this hydrologic alteration may prevent the dispersal of dominant plant species such as the upright sedge, *Carex stricta* (Galatowitsch and van der Valk, 1996). Some wetlands, on the other hand, have too much water because of dams. Impounded baldcypress swamps have almost no natural regeneration (Middleton, 2000), and over time, swamps without regeneration will become open water (Xiao and others, 2002). While these "reengineered landscapes" have enabled urban and agricultural development, such modified hydrology thwarts our attempts to restore and maintain natural processes in existing wetlands (Middleton, 1999, 2003).

Figure 1. Old agricultural fields that are no longer being used have often been cut off from water pulsing from rivers and are not likely to regenerate with the species of baldcypress swamps. Discontinuity in flood flow is the culprit and is associated with channel straightening and downcutting, which are themselves associated with channel reengineering for floodplain development and navigation. The scientists in the picture are planting trees along elevations in an old field, where baldcypress once grew. After farming stopped, baldcypress did not grow back (Pictured: Eric Hoyer of Southern Illinois University and Beth Middleton of the U.S. Geological Survey; photo by Brad Ketterling of the Illinois State Geological Survey).

Seed Banks of Baldcypress Swamps and Restoration

Frequent dispersal is critical for the regeneration of these forests because the short-lived nature of the dominant species inhibits the development of a persistent seed bank (seeds stored in the soil). The seeds of woody species in baldcypress swamps typically live for less than 1 year, so in the absence of flood pulsing, new seeds cannot be carried to restoration sites or natural swamps (Middleton, 2000, 2002). Many

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floodplain landscapes no longer have flood pulsing because of reengineering, so the seed banks cannot initiate the regeneration process. Swamps that have been cleared for agriculture, for even as little as 1 year have almost no seed bank of dominant species, baldcypress (Middleton, 2003). The seeds of baldcypress are adapted to seasonal flood pulsing, which occurred regularly on flood plains before the reengineering of these systems to prevent flooding (Middleton, 2002, 2003). In contrast to baldcypress swamps, prairie potholes have some dominant species that can survive in the seedbank for decades regardless of farming (Wienhold and van der Valk, 1989).

Seed Dispersal and Regeneration in Baldcypress Swamps

The green material that floats on the surface of the water in swamps resembles duckweed (*Lemna* spp., *Spirodela* spp.), but it contains everything that is biologically required to make a new swamp (fig. 2). In addition to duckweed, seeds of the dominant species as well as many others float on the surface of the water (Schneider and Sharitz, 1988; Middleton, 2000). When flood pulses are not restricted, the water often carries these seeds to the shoreline, where they can be deposited at the high water mark (fig. 3; Middleton, 2000).

Seeds of woody species will germinate only in the dry, drawdown conditions of the summer season; consequently, if sites are permanently impounded (flooded behind a dam), no regeneration will occur in the swamp, even though seeds are dispersing from the adult trees. Impounded swamps generally have some regeneration at the winter high water mark of the swamp, so a “bathtub ring” of seedlings and saplings grow around the impoundment (fig. 3; Middleton, 2000). Seedlings will die if reflooded during the summer growing season (Middleton, 2002), but good natural regeneration has been observed in situations where drawdown continues for two consecutive years (Keeland and Conner, 1999). In baldcypress swamps, the seed dispersal and seed bank storage systems are remarkably well adapted to the flood pulsed setting in which they evolved, and in fact require flood pulsing for their continuing well-being (Middleton, 2002).

For natural regeneration to occur, appropriate environmental conditions need to be re-created in the restored area. These conditions need to resemble those that originally occurred on the site and for which the species are adapted. Winter flooding also needs to occur so that seeds will be carried to sites that will be drawn down during the growing season. For baldcypress swamps in the Gulf Coastal Plain of the southeastern United States, drawdown needs to occur during the growing season for seeds to germinate and seedlings to grow. Without this flood pulse, most species in baldcypress swamps will not regenerate naturally, and those that cannot reestablish after the death of old individuals will eventually be eliminated from these communities (Middleton, 2000). Furthermore, the inhospitable environment of flood plains caused by the lack of flood pulsing may be responsible for some of the worldwide decline of biodiversity in flood-pulsed wetlands (Middleton, 2003).

Figure 2. Seeds dispersed in baldcypress swamps. The green material on the surface of the water is a microcosm of the swamp. More than 40 species of seeds float in the water, along with whole plants of duckweeds, liverworts, mosses, as well as insects and insect larvae. Everything that is required to make a new swamp floats in the water and simply needs to be carried by water flow to an environment in which a swamp can sustain itself. Consequently, swamps can restore themselves if we provide them with the appropriate landscape connections.

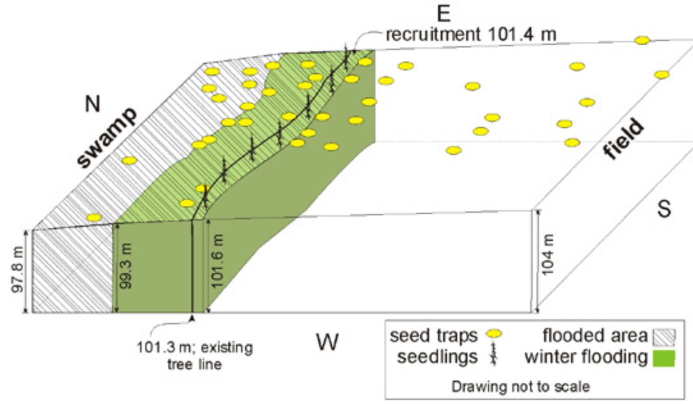

Figure 3. Regeneration patterns of baldcypress in a swamp impounded for restoration. While seeds disperse across the entire swamp in the winter flooding season, (hatched area), germination occurs in draw-down zones at the edge of the swamp (green shaded area). Because seeds do not live very long, no germination occurs above the winter flood zone of the previous winter. Seedlings die if they are reflooded during the growing season, which occurs frequently during summer flooding in an impoundment (green shaded area below the seedling recruitment zone). Because of these life history constraints, regeneration can only occur at the highest level of winter flooding and then only when the seedlings are successful in tracking moisture as groundwater recedes in the summer. The illustration depicts the actual regeneration patterns for the 1994 growing season, starting with dispersal patterns in February 1994 in Buttonland Swamp, near Perks, Illinois. This part of southern Illinois is located in the far northern portion of the Gulf Coastal Plain of the southeastern United States (redrawn from Middleton 2000, copyright with Kluwer Academic Publishers, Dordrecht, The Netherlands).

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