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The Flood Pulse Concept in Wetland Restoration

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The reestablishment of flood pulsing in riverine and tidal systems is becoming recognized as an essential step in the restoration of wetlands worldwide. Especially in North America, monitoring of projects that have incorporated more natural water regimes is now under way. In most instances, researchers are still collecting the essential life history data that will aid in building a case for the need to recreate flood-pulsed hydrology in wetland restoration projects. In this book, each chapter examines a case history of one these projects, written by a field researcher close to the heart of this rapidly developing field.

The flood pulse concept was first developed to describe seasonal changes in water levels on Amazonian floodplains and their relationships to functional dynamics and the maintenance of species diversity (Junk, 1982, 1997; Junk and Howard-Williams, 1984; Junk et al., 1989; National Research Council, 1992; Bayley, 1995) (Figure 1-1). The interconnection of the river channel and floodplain is critical because functions such as production, decomposition, and consumption are driven by the flood pulse (Grubaugh and Anderson, 1988; Sparks et al., 1990) and water fluctuation drives succession (van der Valk, 1981; Finlayson et al., 1989; Niering,

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1994; Middleton, 1999a). Although this idea emerged from the study of large river ecosystems, there is growing recognition that tidal pulsing is also important in salt marshes (Niering, 1994; Turner and Lewis, 1997; Zedler and Callaway, 1999) and mangrove swamps (McKee and Faulkner, 1999). In addition, isolated restored sedge meadows in the Prairie Pothole Region have lower species richness than natural wetlands that developed while large floods still occasionally interconnected them (van der Valk, 1999).

Although the importance of the flood pulse is recognized for a variety of wetland types worldwide, the idea that it is necessary to reestablish a functional flood or tidal pulse in damaged systems has been adapted rather slowly by wetland restorationists. In fact, it is not yet known whether the restoration of flood pulsing restores function (Brookes et al., 1996), and at least some evidence shows that in and of itself, flood pulsing is not enough. For example, merely reopening a tidal channel may not restore salt marsh function if the soil structure is altered and/or too saline (Haltiner et al., 1997). Regardless of what else may have to be adjusted, reestablishment of the original water dynamics (and sometimes soil conditions) is a critical aspect of wetland restoration, even more than reestablishing the vegetation.

To restore a wetland, most often what is required is a reversal of the engineering that dried the wetland in the first place—that is, dam removal, dechannelization, remeandering, addition of debris, rediversion of water, cessation of water extraction, levee or polder removal. The reengineering at a landscape level that is often required for such change is not easy, either physically or politically. However, simpler and widely used approaches such as damming create static water levels and so are not adequate restoration approaches (Middleton, 1999b, 2000).

The alteration of riverine and coastal ecosystems worldwide is so widespread as to leave us few examples of systems that still have a natural hydrologic regime (Sparks et al., 1990; Petts et al., 1992; Junk, 1999). This is especially true in temperate areas of the world; in the 139 largest river systems in Europe, the republics of the former Soviet Union, and regions north of Mexico, 77 percent of their total discharge is affected by dam and reservoir operation, interbasin diversion, and irrigation (Dynesius and Nilsson, 1994). Water extraction along rivers is also causing salt water intrusion in fresh and brackish water coastal systems (Muñoz and Prat, 1989; Prat and Ibañez, 1995). Along rivers in industrialized countries,

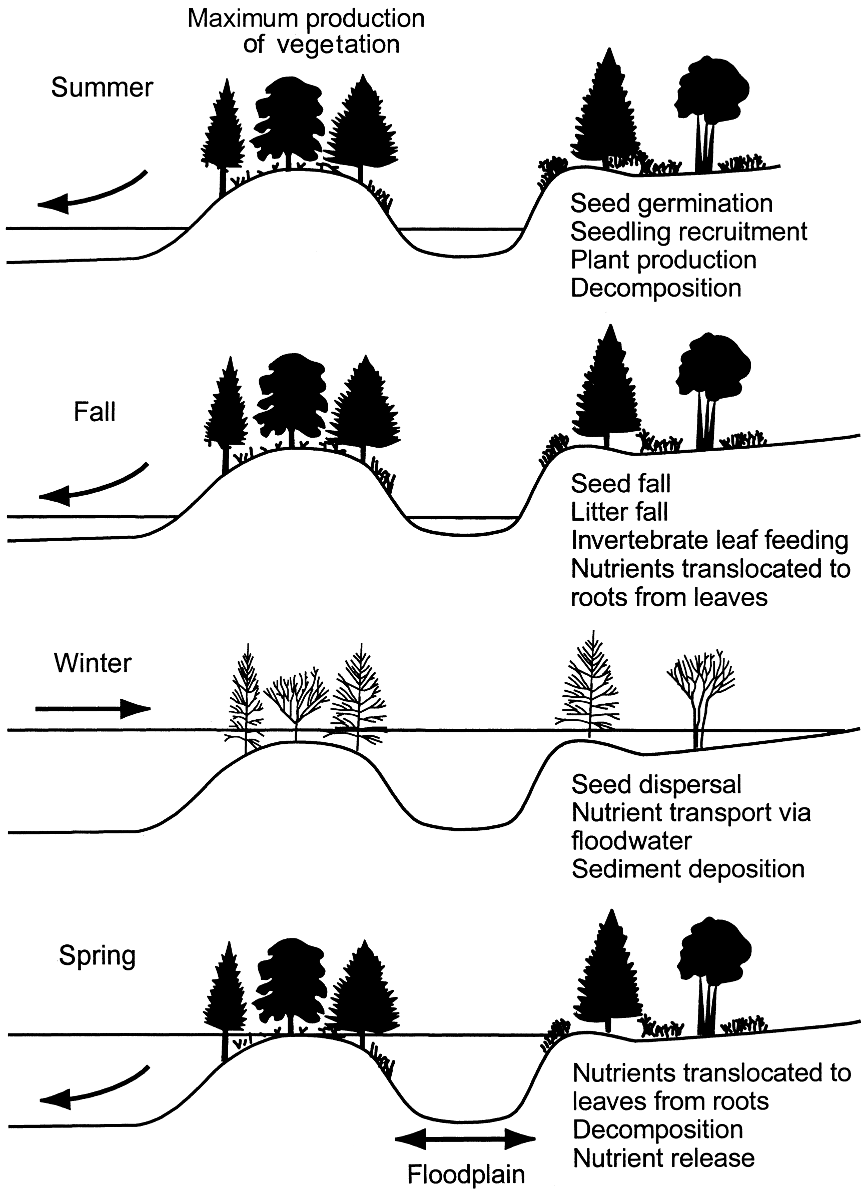

Figure 1-1. *Flood pulsing across a forested floodplain in various seasons in North America, related functional dynamics and biotic adaptations. (Adapted from Bayley, 1991, as derived from Junk et al., 1989, in Middleton, 1999b.)*

natural flood regimes are almost absent as a result of the reengineering of waterways (Bayley, 1995). Nevertheless, a few northern rivers that have been reengineered have portions that still flood pulse—for example, the Illinois (Sparks et al., 1998) and the Danube Rivers (Heiler et al., 1995).

After levees were constructed along major rivers such as the Mississippi, floodplains were converted to other uses, such as agriculture (Allen, 1997). If people move onto a floodplain after the completion of a water control project, it is often politically impossible to initiate the types of reengineering measures necessary for flood pulsing on the flood or tidal plain. Yet sudden, destructive floods sometimes occur on reengineered floodplains, so that a certain amount of rethinking is occurring recently. Is it really wise for us to restrict a river to its immediate channel and thus allow the encroachment of the floodplain, which exposes people to the threat of dangerous floods (Interagency Floodplain Management Review Committee, 1994; Junk, 1999)? In cases where the threat of future flooding is likely, portions of flood or tidal plains may be designated as nature areas to provide for flood storage (Zinke and Gutzweiler, 1990; Lathbury, 1996). Chronically flooded sites present some opportunities for the use of flood pulsing in restoration, albeit on a small scale. Nevertheless, there are some recent examples where flood-pulsed conditions have been (or are being) restored on a regional or landscape scale because of public demand, such as on the Kissimmee River (see Chapter 6). Unfortunately, because of the danger of flooding private property, restoration projects have usually been limited to ineffective measures, such as impounding waterways, that do not provide the biota with the pulsing environment to which they are adapted (Middleton 1999b).

The importance of reestablishing water regimes in sync with seasonal climate fluctuation and water flow in riverine and tidal systems has not been fully appreciated in wetland restoration. Organisms have specific adaptations that allow them to tolerate the wet/dry conditions that are a part of a flood-pulsed environment (Junk, 1997; Middleton, 1999a). Not only does each species have different water requirements and tolerances, these differ for each life stage—seed, seedling, and adult (see Chapters 2, 4, 5 and 7).

Damming, one of the most common river regulation procedures, is illustrative of the problems created by altered environments for biota (Middleton 1999b). Upstream, the reservoir above the dam becomes permanently impounded, resulting in a replacement of riparian vegetation with algal or submerged communities. Downstream from the dam, flows in the stream channel are altered, which changes the nature of the pulse transmitted to the floodplain (Middleton 1999b). Sediments become trapped behind the dam, so downcutting and erosion occur in the downstream channel, further cutting off the channel from the floodplain (Petts and Lewin, 1979; Hickin, 1983; Petts, 1984).

Permanent flooding lowers the overall species richness along regulated rivers because the sites never draw down (Nilsson et al., 1997). The dry phase of the flood pulse is critical, because even the most flood-tolerant species will eventually die in anaerobic conditions (Crawford, 1983; Armstrong et al., 1994) even though such species possess many mechanisms to survive periods of inundation (Crawford and Braendle, 1996; McKevlin et al., 1998). The long-term effects of impoundment in reservoirs indicate that when a river margin is permanently flooded, many species are lost, as was demonstrated in a study of eight Swedish rivers (Jansson et al., 2000b).

Impoundment is often used in restoration as a means of increasing water levels in a dried wetland, but because of the lack of a flood pulse, regeneration—from seed dispersal to the seedling recruitment stage—is problematic (Middleton, 1999b, 2000). Dams inhibit the movement of hydrochorous seeds because of fragmentation and low current velocity, and this affects seed availability along the corridor; as a result, each impoundment develops a distinctive flora (Jansson et al., 2000a) (Figure 1-2). In addition, because impoundment reduces dispersal distance, impoundments are likely inhabited by individuals that are more closely related to each other (Jansson et al., 2000a). The impacts of dams on flora were still apparent 65 km downstream of dams along six rivers in Virginia (Schneider et al., 1989). River regulation also has severe impacts on fauna; it desynchronizes environmental cycles and thus disrupts reproductive cycles of fish (Welcomme, 1989; Gehrke et al., 1995; Junk, 1997) and migrations of invertebrates (Adis et al., 1996).

Successful restoration depends on a better understanding of the life history requirements of plants and animals (Chapters 2 to 6). Seed germination can be critically dependent on flood pulsing, with the high phase of the pulse necessary for dispersal and drawdown necessary for germination (Junk and Piedade, 1997; Middleton, 1999b, 2000). Without a flood pulse, the dispersal of some species, such as *Taxodium distichum* and *Populus* spp., to suitable elevations for germination during the growing season is

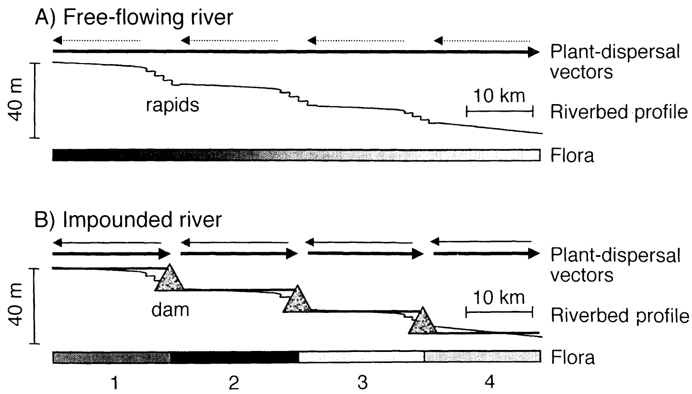

Figure 1-2. *Hypothesized relationships between plant-dispersal vectors, riverbed profile, and composition of the riparian flora in free-flowing versus impounded rivers.* (A) *The flora in the free-flowing river is hypothesized to describe a gradual change downstream, whereas* (B) *in the regulated river, each impoundment is projected to develop an individual flora (denoted 1–4). (From Jansson et al., 2000a, copyright © Ecological Society of America; reprinted by permission.)*

hampered (Chapters 7 and 5, respectively). Certain endangered species such as *Boltonia decurrens* on the Illinois River cannot germinate and set seed without a flood pulse (Chapter 4). Seed germination can also be sensitive to other environmental factors, such as salinity (Galinato and van der Valk, 1986; Baldwin et al., 1996), temperature, substrate, pH, and light quality (Baskin and Baskin, 1998). At the same time, floods remove the debris that sometimes decreases the germinability of seeds (Chapter 3). Species become increasingly tolerant of flooding as plants mature (Chapter 7). By the adult stage, water tolerance is widely variable between species and forms the basis for the compositional differences of wetlands (Harris et al., 1975; Whitlow and Harris, 1979; Hook, 1984; Theriot, 1993; Middleton, 1999b). Unfortunately, water for restoration purposes in the arid West may be so limited by competing demands by humans that restoration may be nearly impossible (Chapter 2).

River regulation impacts the flood pulsing environment experienced by flora and fauna on flood and coastal plains, which is critical in the life history dynamics of these species. Without proper attention to the hydrologic setting created, attempts at wetland restoration will fail. This book reviews the case histories of restoration situations where either flood pulsing has been reestablished as part of the project, or extensive studies of the life history requirements of species that are likely to need flood pulsing are being conducted.

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