7-1-2000

Wetland Seed Banks: Research in Natural and Created Wetlands

Douglas A. DeBerry
Virginia Institute of Marine Science

James E. Perry
Virginia Institute of Marine Science

Virginia Institute of Marine Science, Wetlands Program

Wetlands Program

Technical Report

Summary 2000 No. 00-4

Wetland Seed Banks:
Research in Natural and Created Wetlands

By Douglas A. DeBerry and James E. Perry

Introduction

Wetland creation and restoration projects have become more prevalent in recent years in the United States with the advancement of wetland policy and regulation (Kusler and Kentula 1989, Mitsch and Gosselink 1993). Through the concept of mitigation as a management alternative for wetland losses, creation and restoration are now viewed as acceptable approaches for the replacement of lost wetland functions (Reinhartz and Warne 1993, Brown 1998).

One of the most important structural components of the wetland ecosystem– the seed bank– is of critical importance to the establishment and development of vegetation communities in wetlands (van der Valk 1981, figure 1.). The presence of viable seeds in the soil will direct the revegetation sequence following grading or disturbance (e.g. flooding). This is particularly true for created and restored wetland systems that are graded or otherwise manipulated to implement or reintroduce a favorable hydrologic regime and are left to develop without planting or the addition of soil amendments (van der Valk and Penderson 1989, Atkinson *et. al.* 1993, Mitsch and Gosselink 1993, Brown 1998). In addition, planting or seeding of wetland species, a common practice at creation and restoration sites, may influence recruitment of naturally colonizing vegetation from the seed bank (Reinhartz and Warne 1993). The latter affects the presence of desirable and undesirable species within the community. Therefore, a preliminary understanding of the potential for vegetation development from the seed bank is essential for understanding plant community succession and future management considerations of created or restored wetland ecosystems.

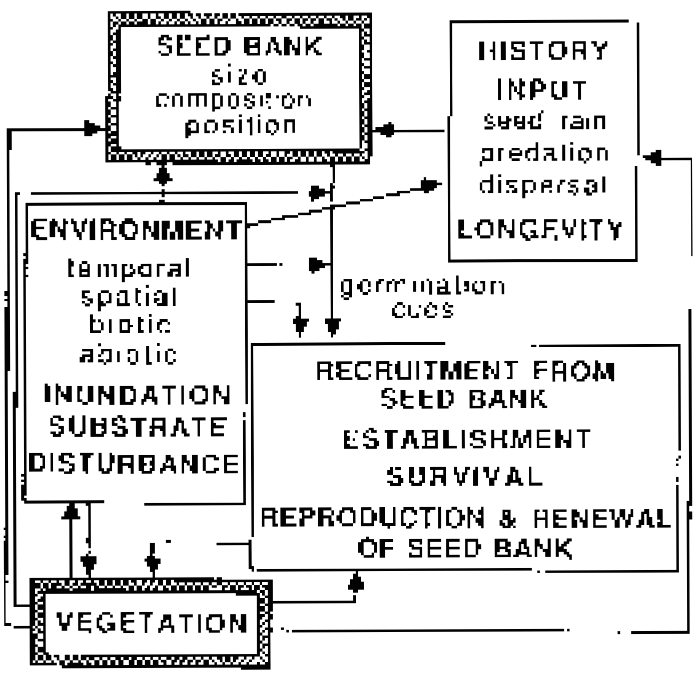

Figure 1. Relationship between wetland seed banks, vegetation, and environment (from Leck 1989).

Although the importance of a viable seed bank in developing wetland plant communities is acknowledged in the literature, seed bank studies in created or restored wetlands are surprisingly limited. The purpose of this report is two fold: 1) to provide a review of research on wetland seed banks; and, 2) to relate these studies to management alternatives in created and restored wetlands. A general overview of wetland seed banks, including seed physiology, ecology, and the current understanding of wetland seed bank dynamics, is discussed in technical report number 00-2, Spring 2000.

Historical Perspective

Much of the influential work on wetland seed banks in the United States has been accomplished by authors such as van der Valk (van der Valk and Davis 1978, van der Valk 1981), Keddy (Keddy and Reznicek 1982, Keddy and Constabel 1986), Smith and Kadlec (1983, 1985), and Leck (Parker and Leck 1985, Leck 1989). The work of van der Valk has concentrated on seed bank dynamics in prairie glacial wetlands. His most influential contribution has been the development of a qualitative model for predicting vegetation recruitment from the seed bank during favorable conditions (van der Valk 1981). The model was developed using relevant life history features of the species present in the soil seed bank (life span, propagule longevity, and propagule establishment requirements), and has been found to be a reasonably accurate predictor of vegetation composition following drawdown (Thompson 1992). Most of the information needed to apply the model can be obtained from examination of the seed bank.

Similar influential work has been accomplished by Keddy (Keddy and Reznicek 1982) in lakeshore wetlands, Kadlec (Smith and Kadlec 1983) in saline environments, and Leck (Parker and Leck 1985) in tidal freshwater wetlands. A complete review of the conceptual principles derived from these and other influential studies is beyond the scope of this work; however, some generalities are summarized in technical report number 00-2. A comprehensive review can be found in Leck (1989) and Thompson (1992).

Recent Seed Bank Research in Natural Wetlands

The effect of drawdown frequency and hydrologic regime on seedling emergence has been the subject of several recent wetland seed bank studies. Many of these have reinforced the concept that drawdown frequency, as a disturbance regime, can direct vegetation recruitment and establishment from the seed bank. Gerritsen and Greening (1989), Leck and Simpson (1995), and Leck (1996) recognize three classes of germination requirement in annual plants: 1) dry germinating (oxygen requiring) plants such as beaked rushes (*Rhynchospora* spp.) and sedges (*Carex* spp.); 2) wet germinating (hypoxic) individuals represented by taxa such as scented water-lily (*Nymphaea odorata*) and yellow bladderwort (*Utricularia lutea*); and, 3) generalists (germinating regardless of soil moisture or oxygen content) such as the spikerush (*Eleocharis* spp.). Bonis *et. al.* (1995) concluded from research on temporary Mediterranean marshes that an unpredictable hydrologic regime delays the effects of competitive exclusion, allowing annuals and seed bank species to become established and persist in the system. In contrast, Leck (1996) noted that the more predictable hydroperiod of tidal freshwater wetlands yields a more transient seed bank, an indirect result of larger-sized seed production for greater germination success at

Wetlands Program
School of Marine Science
Virginia Institute of Marine Science
College of William and Mary
Gloucester Point, Virginia 23062
(804) 684-7380

Dr. Carl Hershner, Program Director
Dr. Kirk Havens, Editor
Published by: VIMS Publication Center

This technical report was funded, in part, by the Virginia Coastal Resources Management Program of the Dept. of Environmental Quality through Grant #NA97O20181-01 of the National Oceanic and Atmospheric Administration, Office of Ocean and Coastal Resources Management, under the Coastal Zone Management Act of 1972, as amended.

The views expressed herein are those of the authors and do not necessarily reflect the views of NOAA or any of its subagencies or DEQ.

Commonwealth's Declared Policy: "to preserve the wetlands and to prevent their despoliation and destruction..."

Printed on recycled paper.

increased burial depths. Corroborating evidence for hydrologic control of germination in wetlands is offered by Haukos and Smith (1994) in playa wetlands, and Gerritsen and Greening (1989) in freshwater marshes.

Other environmental and biological parameters also influence recruitment from the seed bank. Among these, sediment accretion (Bonis and Lepart 1994, Jurik *et. al.* 1994, Giroux and Bédard 1995) and soil salinity (Shumway and Bertness 1992) are negatively correlated with seedling emergence. Studies on seed size have shown that smaller seeds are generally more persistent in the soil and tend to form seed banks, while larger seeds maintain a more transient presence in the soil (Leck 1996, Raffaele 1996). Finally, in a study of seed banks in beaver pond wetlands, Le Page and Keddy (1998) concluded that the age of the wetland does not affect species abundance or diversity in the seed bank, although this result may not be found in all wetlands (Leck 1989).

Testing the use of seed bank data as a predictive tool for determining vegetation succession has demonstrated variable results. ter Heerdt and Drost (1994) showed that van der Valk's (1981) model of succession in freshwater wetlands is useful for long-term vegetation predictions in marshes; however, they indicated that the model could be improved with additional information regarding environmental parameters. Gerritsen and Greening (1989) further suggested that predictions may be accurately made if the hydrologic regime is understood. In a unique study on hydroperiod and seed bank composition, Poiani and Johnson (1989) concluded that the prevailing hydrologic regime in a freshwater marsh may be predicted by the presence of seeds in the sediment. Their work suggests that a dominance of annual plant seeds may indicate short hydroperiods while low seed densities may indicate longer hydroperiods. They conclude that in lieu of long-term and costly hydrology monitoring, a simple and inexpensive seed bank assay may be an efficient means of predicting hydroperiod.

Recent Seed Bank Research in Created or Restored Wetlands

Although seed bank studies in created and restored wetlands are poorly represented in the literature, a few recent publications deserve note.

Created Wetlands

Reinhartz and Warne (1993), in a study of created depressional wetlands in Wisconsin, showed that close proximity to existing wetlands, and increased perimeter complexity, increased species diversity and cover in the created marshes. In addition, sites that were manipulated by seeding of native wetland species showed greater diversity and cover, and a lower presence of invasive plant species (e.g. *Typha latifolia*). Stauffer and Brooks (1997) achieved similar results when studying "salvaged" marsh surface soils and leaf litter compost as amendments to created wetland soils. Salvaged marsh surface treatments increased vegetation complexity in the wetlands, and compost treatments increased soil moisture retention in favor of planted species establishment.

In a review of management alternatives for experimental wetlands in California, Mushet *et. al.* (1992) concluded that seed production is not significantly increased by irrigation in these systems, and that irrigation does not represent an effective management tool to enhance wetland species establishment. However, Thullen and Eberts (1995) found that seed preparation including stratification (i.e. cold treatments, wherein seeds are arranged in layers or "stratified"), increases germination rates in *Scirpus acutus*, an important species used in constructed wetlands.

Restored Wetlands

In a recent study of seed banks at restored sites on historically drained agricultural fields, Brown (1998) showed that remnant wetland species present in ditches and low, unaltered regions of the fields were more similar to the subsequent restored vegetation than were seed bank species. Analysis, therefore, of remnant wetland species was more effective than seed bank analysis at predicting early restoration site succession. However, seed bank studies were significant in identifying invasive species which have the potential to proliferate the restored vegetation.

Brown and Bedford (1997) showed that transplanting soils from adjacent ditches at restoration sites increases species diversity and cover. In addition, mowing and plowing increases wetland species complexity in the restored vegetation, but also increases the presence of invasive plant species (e.g. *Typha latifolia*).

Brown (1998) also concluded, as did Weinhold and van der Valk (1989), that the length of time following drainage of potential restoration sites significantly reduces the presence of wetland species in the seed bank. Hence, recently drained sites offer better opportunities for reclamation of native wetland species by seed bank recruitment.

Implications for Management

It has been suggested in the literature that seed banks offer an opportunity for accurate prediction of early successional vegetation establishment in wetlands (Thompson 1992, ter Heerdt and Drost 1994). However, as Brown (1998) points out, the reliability of seed bank data prior to manipulation of creation and restoration sites is limited. This is due to the fact that creation sites are generally excavated from uplands (Atkinson *et. al.* 1993), where the presence of seeds from wetland species is assumed to be minimal or altogether lacking. Likewise, restoration sites have often been drained for several years prior to manipulation, and are therefore depleted of wetland seed reserves due to burial, predation, or physiological death (Weinhold and van der Valk 1989). In either case, a more prudent allocation of time during the feasibility stage of creation and restoration projects may be to review the vegetation in existing, adjacent wetlands or in field ditches. Dominant annual species in these areas are more likely to colonize the site when hydrologic conditions are finally established.

It is clear from the literature, that hydrology plays an important role in seed bank recruitment and vegetation establishment (van der Valk 1981, Welling *et. al.* 1988, Gerritsen and Greening 1989, van der Valk and Penderson 1989, Haukos and Smith 1994, Bonis *et. al.* 1995, Leck 1996). Therefore, it is important to understand the germination requirements for the species desired in a planned wetland. Information on the reproductive phenology of the desired species may be obtained from manuals, floras, monographs and revisions of the taxa under study, peer-reviewed experimental research, and vegetation ecology textbooks or related works. Invariably, a mechanism for controlling the amount of water retention onsite is needed to maintain water levels within the appropriate threshold for germination of the species desired (van der Valk and Penderson 1989). Such a mechanism may include a dike or ditch system that can be selectively manipulated to drain or retain water in the wetland.

The use of seeding and soil amendments on creation and restoration sites is recommended, provided the species seeded are native to the natural wetlands in the region (Reinhartz and Warne 1993, DeBerry and Perry unpublished data). If seeds are to be collected and sown on the site, a preliminary stratification (chilling) treatment may increase germination rate and establishment in the wetland (Thullen and Eberts 1995). This may be an important preparatory method for seeds of tree species, which generally do not form persistent seed banks (Leck 1989). Transplanted wetland soils have been shown to increase species diversity and cover on created and restored sites (Brown and Bedford 1997, Stauffer and Brooks 1997); however, the availability of such resources may be restricted by governmental regulation of excavation activities in wetlands. The use of organic amendments is also recommended. Such amendments increase water holding capacity and decrease temperature extremes in the soil, conditions favorable for the germination of wetland species (Stauffer and Brooks 1997). Organic materials are often inexpensive to generate (e.g. leaf compost), and can usually be found on the site prior to construction or manipulation.

Control of invasive species in created or restored sites is a continual battle. The problem may be significantly reduced in the early stages of site development by seeding native wetland species. As Reinhartz and Warne (1993) indicate, an early introduction of a diversity of wetland species may enhance long-term diversity by allowing desirable species to occupy space which would otherwise be quickly colonized by invasive plants (e.g. *Phragmites australis, Typha latifolia, Lythrum salicaria*). The success of invasive species is largely due to the ability of these plants to propagate by both seed and rhizome. Management techniques to control populations of invasive plants include application of herbicides, flooding, irrigation, drying, disking, plowing, burning, or combinations of these treatments (van der Valk and Penderson 1989). If populations are small, a recommended technique includes physical removal of all above- and belowground organs prior to seed set, which will reduce the presence of the undesirable species in the seed bank.

The culmination of seed bank research in wetlands should result in unifying concepts of seed bank dynamics in these systems. Although the most significant research has only been conducted within the last two decades, many useful generalizations have been made. Our current state of understanding is increasing, but much research remains before predictions of vegetation succession can be accurately made from seed bank data. Particularly in created and restored wetlands, the lack of reference seed bank studies limits the usefulness of interpreting seed bank data during the feasibility and planning stages in wetland mitigation projects. Future seed bank research should therefore include an increase of the different types of wetland sites studied, rather than an emphasis on changes in research methods. In addition, early successional environments such as those of created and restored wetland sites offer an opportunity for study of seed banks as they are forming. This may lead to a better understanding of where seeds originate, how dispersal is accommodated, and to what degree seeds migrate through a relatively young substrate.

References

Atkinson, R. B., J. E. Perry, E. Smith, and J. Cairns, Jr. 1993. Use of created wetland delineation and weighted averages as a component of assessment. Wetlands 13: 185-193.

Bonis, A. and J. Lepart. 1994. Vertical structure of seed banks and the impact of depth of burial on recruitment in two temporary marshes. Vegetatio 112:127-139.

Bonis, A., J. Lepart, and P. Grillas. 1995. Seed bank dynamics and coexistence of annual macrophytes in a temporary and variable habitat. Oikos 74:81-92.

Brown, S. C. 1998. Remnant seed banks and vegetation as predictors of restored marsh vegetation. Canadian Journal of Botany 76:620-629.

Brown, S. C. and B. L. Bedford. 1997. Restoration of wetland vegetation with transplanted wetland soil: an experimental study. Wetlands 17: 424-437.

Gerritsen, J. and H. S. Greening. 1989. Marsh seed banks of the Okefenokee Swamp: effects of hydrologic regime and nutrients. Ecology 70:750-763.

Giroux, J. and J. Bédard. 1995. Seed production, germination rate, and seedling establishment of *Scirpus pungens* in tidal brackish marshes. Wetlands 15:290-297.

Haukos, D. A. and L. M. Smith. 1994. Composition of seed banks along an elevational gradient in playa wetlands. Wetlands 14:301-307.

Jurik, T. W., S. Wang, and A. G. van der Valk. 1994. Effects of sediment load on seedling emergence from wetland seed banks. Wetlands 14:159-165.

Keddy, P. A. and P. Constabel. 1986. Germination of ten shoreline plants in relation to seed size, soil particle size and water level: an experimental study. Journal of Ecology 74:133-141.

Keddy, P.A. and A.A. Reznicek. 1982. The role of seed banks in the persistence of Ontario's coastal plain flora. American Journal of Botany 69:13-22.

Kusler, J. A., and M. E. Kentula. 1989. Executive summary p. xi-xix. *In* J. A. Kusler and M. E. Kentula (eds.). Wetland creation and restoration: the status of the science. U.S. Environmental Protection Agency 600/3-89/038b.

Leck, M. A. 1996. Germination of macrophytes from a Delaware River tidal freshwater wetland. Bulletin of the Torrey Botanical Club. 123:48-67.

Leck, M.A. 1989. Wetland seed banks. *In:* Leck, M.A., V.T. Parker, and R.L. Simpson (eds.). 1989. *Ecology of Soil Seed Banks*. Academic Press, Inc., San Diego, CA. pp. 283-305.

Leck, M. A. and R. L Simpson. 1995. Ten-year seed bank and vegetation dynamics of a tidal freshwater marsh. American Journal of Botany 82:1547-1557.

Le Page, C. and P. A. Keddy. 1998. Reserves of buried seeds in beaver ponds. Wetlands 18:242-248.

Mitsch, W. J., and J. G. Gosselink. 1993. *Wetlands.* Van Nostrand Reinhold, New York, NY, USA. 722 pp.

Mushet, D. M., N. H. Euliss, Jr., and S. W. Harris. 1992. Effects of irrigation on seed production and vegetative characteristics of four moist-soil plants on impounded wetlands in California. Wetlands 12:204-207.

Parker, V. T. and M. A. Leck. 1985. Relationships of seed banks to plant distribution patterns in a freshwater tidal wetland. American Journal of Botany 72:161-174.

Poiani, K. A. and W. C. Johnson. 1989. Effect of hydroperiod on seed bank composition in semi-permanent prairie wetlands. Canadian Journal of Botany 67:856-864.

Raffaele, E. 1996. Relationship between seed and spore banks and vegetation of a mountain flood meadow (mallín) in Patagonia, Argentina. Wetlands 16:1-9.

Reinhartz, J. A. and E. L. Warne. 1993. Development of vegetation in small created wetlands in southeastern Wisconsin. Wetlands 13:153-164.

Shumway, S. W. and M. D. Bertness. 1992. Salt stress limitation of seedling recruitment in a salt marsh plant community. Oecologia 92:490-497.

Smith, L. M. and J. A. Kadlec. 1983. Seed banks and their role during drawdown of a North American marsh. Journal of Applied Ecology 20:673-684.

Smith, L. M. and J. A. Kadlec. 1985. The effects of disturbance on marsh seed banks. Canadian Journal of Botany 63:2133-2137.

Stauffer, A. L., and R. P. Brooks. 1997. Plant and soil responses to salvaged marsh surface and organic matter amendments at a created wetland in central Pennsylvania. Wetlands 17: 90-105.

ter Heerdt, G.N.J. and H.J. Drost. 1994. Potential for the development of marsh vegetation from the seed bank after a drawdown. Biological Conservation 67:1-11.

Thompson, K. 1992. The functional ecology of seed banks. *In:* Fenner, M. (ed.). 1992. *Seeds: The Ecology of Regeneration in Plant Communities.* CAB International, Wallingford, Oxon, UK. pp. 231-258.

Thullen, J. S. and D. R. Eberts. 1995. Effects of temperature, stratification, scarification, and seed origin on the germination of *Scirpus acutus* Muhl. seeds for use in constructed wetlands. Wetlands 15:298-304.

van der Valk, A. G. 1981. Succession in wetlands: a Gleasonian approach. Ecology 62:688-696.

van der Valk, A. G. and C. B. Davis. 1978. The role of seed banks in the vegetation dynamics of prairie glacial marshes. Ecology 59:322-335.

van der Valk, A.G. and R.L Penderson. 1989. Seed banks and the management and restoration of natural vegetation. *In:* Leck, M.A., V.T. Parker, and R.L. Simpson (eds.). 1989. *Ecology of Soil Seed Banks*. Academic Press, Inc., San Diego, CA. pp. 329-346.

Welling, C. H., R. L. Pederson, and A. G. van der Valk. 1988. Recruitment from the seed bank and the development of zonation of emergent vegetation during a drawdown in a prairie wetland. Journal of Ecology 76:483-496.

Weinhold, C. E. and A. G. van der Valk. 1989. The impact of drainage on the seed banks of northern prairie wetlands. Canadian Journal of Botany 67:1878-1884.