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A Drawdown Flora in Virginia

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ABSTRACT

Species composition and relative dominance (cover) were documented in an emergent macrophyte community on recently exposed sediment during an artificial drawdown of a large reservoir in the Coastal Plain of Virginia. Observations included nine county records (New Kent County), four of which were records for the Lower Peninsula of Virginia and are considered state rare species. Dominance calculations by distance class (five-meter increments from the original shoreline to the existing waterline) showed that certain species were locally dominant near the original shoreline (e.g., *Fimbristylis autumnalis*), whereas others, particularly the state rare species, were more prevalent near the drawdown waterline (e.g., *Lipocarpha micrantha*). These results suggest that the timing and magnitude of drawdown events may influence recruitment of the species observed in this study. These species appear to form seedbanks in the substrate of the reservoir for long periods of time, and are capable of rapid germination and regeneration (seed set) during short-lived, unpredictable drawdown conditions. Small seed size and other environmental factors accommodate a predisposition to this "temporal" niche. Based on this research and the work of others, we suggest that such species are part of a regional "drawdown flora."

INTRODUCTION

Seedbank studies in freshwater aquatic habitats have historically focused on emergent wetlands (DeBerry and Perry 2000a, 2000b; Leck 1989). Field studies on these systems have related the importance of surface water dynamics and the timing of drawdown events to the storage, persistence, viability, and regeneration of species via seedbanks (van der Valk 1981). A "drawdown event" is a period of time when surface water has evaporated or has otherwise been removed, rendering previously submerged sediments exposed (van der Valk and Davis 1978). Drawdowns are typically associated with climatic events such as droughts (Poiani and Johnson 1988), but may also be induced by anthropogenic effects (e.g., the breach of a dam or manipulation of the water level within a man-made reservoir). Although drawdowns and seedbank dynamics have been studied extensively in wetland habitats, very little research has been conducted on exposed substrates of larger water bodies such as ponds, lakes, reservoirs, and rivers.

This lack of attention may be understood from three generalizations: (1) permanent water bodies are typically regarded as habitat for submersed aquatic vegetation (SAV), species that tend to reproduce vegetatively and/or do not tend to form seedbanks (Cronk and Fennessy 2001); (2) significant drawdowns in larger water bodies require extreme climatic or anthropogenic events, and such events are infrequent (i.e., 5–10 year return interval); and, (3) drawdowns in these habitats typically respond to stochastic events (e.g., drought) and are therefore difficult to predict or study in nature (Poiani and Johnson 1988). However, in the limited available literature on this subject, two important concepts emerge.

First, lakeshore and pondshore species tend to exhibit zonation with respect to distance away from the shoreline (Riis and Hawes 2002, Odland and del Moral 2002). During the normal

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state of conditions when the water body is at or near normal pool elevation, the zonation appears to be related strictly to water depth. However, during a drawdown, the normal stress of inundation is removed, yet zonation may still be expressed on the newly exposed sediments (Riis and Hawes 2002, Keddy and Constabel 1986). This pattern may result from the timing of water level recession (ter Heerdt and Drost 1994, Tyndall et al. 1990, Welling et al. 1988), and as such may still be in response to inundation regime, with recruitment responding to differential exposure of sediments, length of exposure, and availability of seeds (Haukos and Smith 1994, van der Valk 1981, van der Valk and Davis 1978).

Second, particularly with respect to the eastern United States, there appears to be a unique assemblage of emergent macrophytes that inhabits pond shores and, under opportune circumstances, has been observed during drawdown conditions in reservoirs and other water bodies (Zebryk 2004, Sorrie 1994, Ludwig 1996, Zaremba and Lamont 1993). In Virginia (Fernald 1939, 1943; Ludwig 1996), Kentucky and Tennessee (Baskin et al. 2002, Chester 1992, Webb et al. 1988), and in regions as far north as New England and Canada (Zebryk 2004, Zaremba and Lamont 1993, Oldham and Crins 1988, Ceska and Ceska 1980), these species are mentioned in exclusive association with a shoreline community and/or an exposed substrate of a permanent water body. Species such as *Lipocarpha micrantha* (=*Hemicarpha micrantha*), *Oldenlandia boscii*, and *Paspalum dissectum* are unique in this respect, but they are also unique in rarity of distribution — all three are listed on the Virginia state rare vascular plant list (Townsend 2003). It would seem, then, that this type of habitat, characterized by short-lived exposure of normally submerged sediments in an often unpredictable manner and timeframe, could represent a haven for a rare group of plants that are ecologically "tuned" to exploit the chance occasion of drawdown. We had the opportunity to study such an event during the early fall of 1998 on a large reservoir in the Coastal Plain of Virginia.

The purpose of this study was threefold: (1) to document the colonizing vegetation on newly exposed lake sediments following a drawdown event; (2) to determine species dominance for the point-in-time event represented by the drawdown; and, (3) to determine the relationship between distance from the original shoreline and zonation of the dominant species as a reflection of differential seedbank recruitment from the reservoir substrate. From these analyses, and from a review of other relevant studies from the region, we intend to identify certain species that may be implicated as part of a "drawdown flora" characterized by species using permanent water body substrates to perennate in the seedbank for extended periods of time between drawdowns.

METHODS

Study Site

The study site included a portion of Diascund Reservoir in New Kent County, Virginia (Figure 1). This freshwater lake was constructed in 1953 to be used as source of potable drinking water for residents on the Lower Peninsula of Virginia. A man-made earthen dam intersects Diascund Creek at the bottom of the reservoir, establishing normal pool at elevation 7.9 m above mean sea level. The study site was located along the western flank of the Wahrani Swamp branch approximately 1.8 km northeast of the dam. The reservoir as a whole is predominantly surrounded by forested land, a large portion of which is managed for timber production, with agricultural fields and low-density residential areas scattered around the perimeter. A mixture of forested land, residential homes, and passive agriculture/pasture land lies immediate upslope of the study area.

Field visits were conducted in October of 1998 during an artificial drawdown of the reservoir that was initiated to complete improvements to the spillway of the dam. Elevation data provided by Newport News Waterworks (David Morris, pers. comm. 2005) show that the drawdown began in early July 1998, and by October the lake had been lowered approximately 3 m (Figure 2). This resulted in expansive regions of exposed, coarse-grained sandy sediment, in certain places extending more than 100 m out from the original shoreline. The reservoir had returned to normal pool by the end of January of the following year (David Morris, pers. comm. 2005). We first noticed the colonization of an unusual group of low-growing, emergent

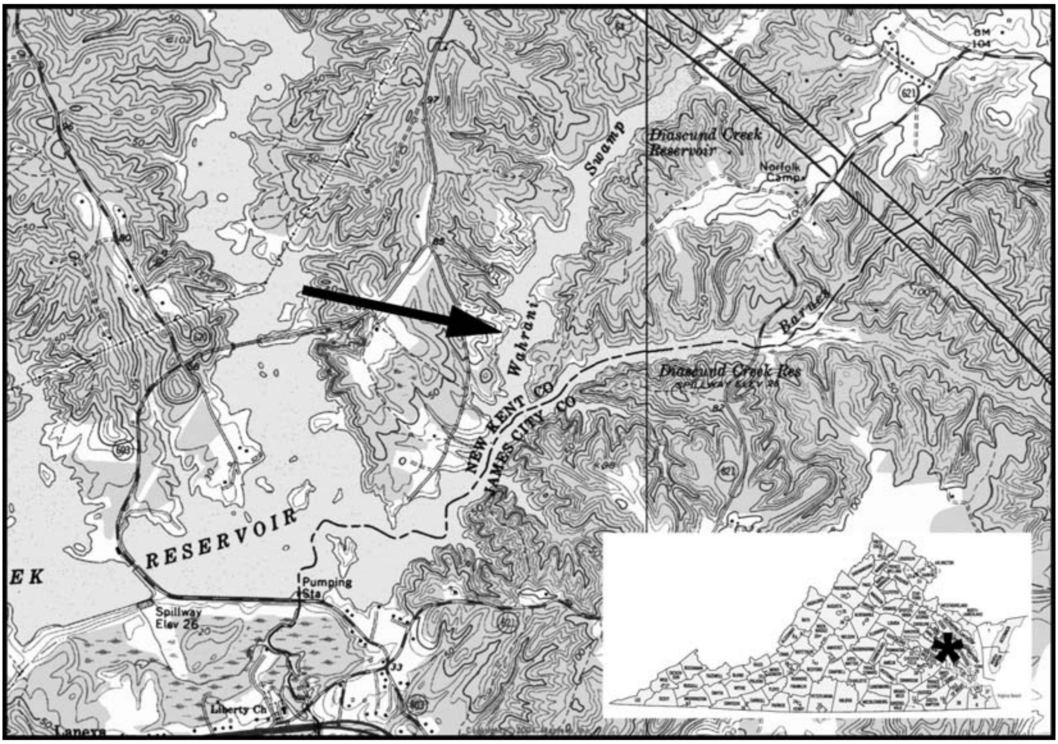

Figure 1. Study site location map. (Source: Maptech Terrain Navigator, Version 5.0; Map not to scale.)

macrophytes in early October of 1998 (Figure 3), and returned to the study site in late October to establish transects and quantify aerial coverage of these species. In general, the growth habit and species composition at the study site reflected the majority of the exposed lake sediments throughout the lower portion of the reservoir.

Sampling

Three transects were laid out perpendicular to the original shoreline, and one-meter square quadrats were established along each transect on five-meter spacing down to the existing waterline. The three transects were 30, 25, and 20 meters in length, respectively, allowing the placement of 18 plots total. The transects were spaced approximately 50 meters apart. At the lowest plots (i.e., the plots along the drawdown waterline), the surface elevation of the sediment was approximately 3 m below normal pool elevation.

All plants within the plots were identified to species according to Radford et al. (1968), Gleason and Cronquist (1991), and Godfrey and Wooten (1979, 1981). Nomenclature follows the Flora of North America Project as cited in U.S. Department of Agriculture Natural Resources Conservation Service (2004). Voucher specimens were deposited at the College of William and Mary Herbarium (WILLI) in Williamsburg, Virginia. Aerial coverage was estimated by species using a modified Daubenmire cover class scale (Meuller-Dombois and Ellenburg 1974), taking the midpoints of the cover classes for data analysis.

Analysis

Overall dominance was calculated by analyzing the relative cover (%) of each species over the entire data set (Causton 1988) and applying the 50:20 rule, which states that dominant species are those that comprise the first 50% of the cumulative total cover added in descending order, and any other species greater than 20% relative cover (Tiner 1999). In addition, species

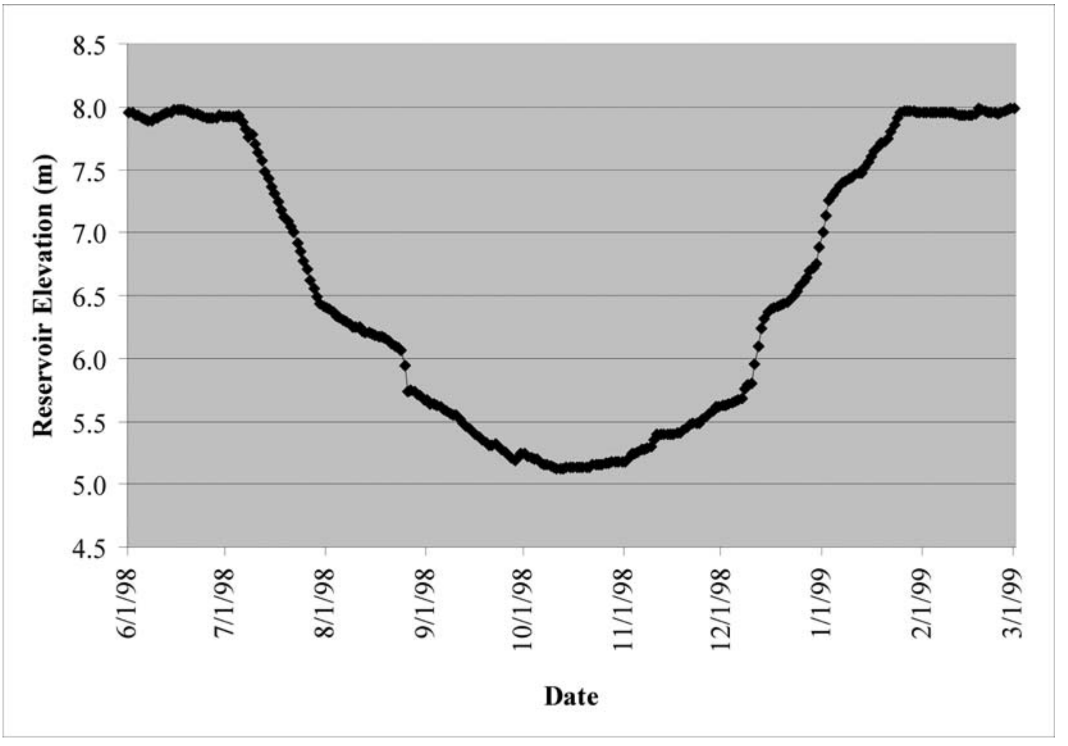

Figure 2. Hydrograph of the reservoir water surface elevation during the artificial drawdown in 1998. Normal pool elevation is approximately 7.9 m above mean sea level. The owner, Newport News Waterworks, began pumping the reservoir down in early July 1998, and by October the water level was approximately 3 m below normal pool. By late January 1999 normal pool elevation had been restored (data provided by Newport News Waterworks).

were grouped by occurrence within a certain distance class (in five-meter increments), over which a Sørenson Similarity Index (SI) matrix was created to analyze differences in species composition with respect to distance away from the original shoreline. SI was calculated by the equation $2c/a+b$, where c is the number of species two groups have in common (in this case, the two groups are distance classes), a is the total number of species in the first group, and b is the total number in second group. Similarity thresholds were established at 0.50 in accordance with Mueller-Dombois and Ellenburg (1974) (i.e., values above 0.50 indicate that the two groups are similar in composition, and those below 0.50 indicate that the two groups are dissimilar). Finally, relative cover was calculated by species for each five-meter increment away from the original shoreline to obtain an estimate of dominance with change in distance.

RESULTS

Twenty species were sampled from 18 plots over the three transects (Table 1). Nine species were noted as records for New Kent County, as follows: *Cyperus erythrorhizos*, *Cyperus polystachyos*, *Eleocharis acicularis*, *Erigeron quercifolius**, *Juncus repens*, *Lipocarpha micrantha**, *Oldenlandia boscii**, *Oldenlandia uniflora*, and *Paspalum dissectum**. Among these, four were identified as records for the Lower Peninsula of Virginia, as indicated by an asterisk above (Harvill et al. 1992). In addition, *Lipocarpha micrantha*, *Oldenlandia boscii*, and *Paspalum dissectum* are tracked by the Virginia Department of Conservation and Recreation Division of Natural Heritage (DNH) as state rare species, and *Erigeron quercifolius* is included on the DNH vascular plant watch list (Townsend 2003).

Figure 3. Diascund Reservoir drawdown within the study area. Photograph was taken in October of 1998. The foreground shows a predominance of low-growth macrophytes supporting a mat-like habit along the exposed sediment.

Four dominants were identified from the overall data set as follows (relative cover in parentheses): *Fimbristylis autumnalis* (15.0%); *Lipocarpha micrantha* (12.8%); *Oldenlandia boscii* (12.7%); and, *Eleocharis acicularis* (12.4%) (Table 1). As noted, two of the dominants (*Lipocarpha micrantha* and *Oldenlandia boscii*) are acknowledged as state rare species by Townsend (2003).

Similarity indices for distance class showed that, as a whole, species composition was relatively homogeneous across the substrate from the original shoreline to the existing water line (Table 2). All SI values exceeded the 0.50 similarity threshold, with the exception of the 0 m to 30 m pairing (0.43). It is possible that this value is attributable to the limited sample size at the 30 m distance (one plot).

Dominant species by distance class (five-meter increments) are provided in Table 3. Among the four overall dominants noted above, *Fimbristylis autumnalis* was most prevalent within 20 meters of the original shoreline (dominant at the 0 m, 5 m, 15 m, and 20 m distance classes). *Lipocarpha micrantha* was only dominant outside of 15 m (dominant at the 15 m, 20 m, 25 m, and 30 m distance classes). The remaining two overall dominants (*Oldenlandia boscii* and *Eleocharis acicularis*) were most prevalent in mid-range distances (10 m to 20 m). Three species of *Cyperus* (*C. polystachyos*, *C. erythrorhizos*, and *C. echinatus*) were also common, with *C. polystachyos* fairly evenly distributed across the substrate. *Oldenlandia uniflora* and *Eragrostis hypnoides* were locally dominant within 5 meters of the original shoreline, as was *Erigeron quercifolius* out near the existing water line (30 m).

DISCUSSION

At Diascund Reservoir, the uniqueness of the emergent community that covered newly exposed sediment during the artificial drawdown of 1998 is reflected in the presence of state rare

Table 1. Species checklist with overall relative dominance, rarity, and New Kent County record data. For state rare species, SR = "State Rare" and WL = "Watch List" in accordance with Townsend (2003). For county records, species denoted with (*) are also records for the Lower Peninsula of Virginia

Scientific Name (common name)	Family	Rarity	County Record	Relative Dominance
Fimbristylis autumnalis (L.) Roemer & J.A. Schultes (slender fimbry)	Cyperaceae			15.0%
Lipocarpha micrantha (Vahl) G. Tucker (smallflower halfchaff sedge)	Cyperaceae	SR	X*	12.8%
Oldenlandia boscii (DC.) Chapman (Bosc's mille graines)	Rubiaceae	SR	X*	12.7%
Eleocharis acicularis (L.) Roemer & J.A. Schultes (needle spikerush)	Cyperaceae		X	12.4%
Cyperus polystachyos Rottb. (manyspike flatsedge)	Cyperaceae		X	11.0%
Oldenlandia uniflora L. (clustered mille graines)	Rubiaceae		X	10.6%
Cyperus erythrorhizos Muhl. (redroot flatsedge)	Cyperaceae		X	9.6%
Eragrostis hypnoides (Lam.) B.S.P. (teal lovegrass)	Poaceae			5.4%
Rotala ramosior (L.) Koehne (lowland rotala)	Lythraceae			2.8%
Cyperus echinatus (L.) Wood (globe flatsedge)	Cyperaceae			2.2%
Juncus repens Michx. (lesser creeping rush)	Juncaceae		X	0.9%
Erigeron quercifolius Lam. (oakleaf fleabane)	Asteraceae	WL	X*	0.9%
Lindernia dubia (L.) Pennell (yellowseed false pimpernel)	Scrophulariaceae			0.8%
Ludwigia palustris (L.) Ell. (marsh seedbox)	Onagraceae			0.7%
Cyperus esculentus L. (chufa flatsedge)	Cyperaceae			0.7%
Panicum dichotomiflorum Michx. (fall panicgrass)	Poaceae			0.6%
Salix nigra Marsh. (black willow)	Salicaceae			0.5%
Eupatorium capillifolium (Lam.) Small (dogfennel)	Asteraceae			0.2%
Hypericum mutilum L. (dwarf St. Johnswort)	Clusiaceae			0.1%
Paspalum dissectum (L.) L. (mudbank crowngrass)	Poaceae	SR	X*	0.1%

species, county records, and the low-growing, dense, mat-like habit of the dominants, which resembled a closely-cropped lawn in some places (see Figure 3). Three questions emerge from these observations. (1) Are certain species within this assemblage unique to unpredictable drawdown habitats? (2) If so, are there common characteristics among these species that might accommodate a predisposition to such environments? (3) Does the distribution of species reflect a discernible zonation? These questions are addressed in the following sections.

Table 2. Similarity Index matrix (2c/a+b). Similarity was high (>0.50) for most distance pairings in five-meter increments away from the original shoreline

Meters	0	5	10	15	20	25
5	0.80					
10	0.71	0.74				
15	0.75	0.79	0.97			
20	0.67	0.69	0.96	0.93		
25	0.64	0.75	0.88	0.85	0.92	
30	0.43	0.53	0.60	0.57	0.63	0.59

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Fernald (1939, 1943), in his historic southeastern Virginia fieldwork during the late 1930s and early 1940s, recalled several encounters with small, unassuming plants such as *Oldenlandia boscii*, *Eragrostis hypnoides*, and *Paspalum dissectum*. In all cases, these sightings were in association with an "exsiccated millpond" or along the shoreline of a drawn down water body. Retracing Fernald's footsteps some 50 years later, Ludwig (1996) searched for rare plant species along the shores of Blackwater River during drawdown conditions in 1993 and 1995. In his searches, Ludwig noted *Lipocarpha micrantha* (=*Hemicarpha micrantha*), *Oldenlandia boscii*, *Eragrostis hypnoides*, and seven other species also found in our Diascund Reservoir study. Similar sightings were reported from the shores of Kerr Reservoir in south-central Virginia during drawdown conditions in the late 1990s (A. Belden, Virginia Division of Natural Heritage, pers. comm. 2004), during studies on reservoir mudflats in Kentucky and Tennessee (Baskin et al. 2002, Chester 1992, Webb et al. 1988), and, particularly with respect to *Lipocarpha micrantha*, from pond and lake shores in New England and Canada (Zebryk 2004, Zaremba and Lamont 1993, Oldham and Crins 1988, Ceska and Ceska 1980).

From these observations, we are compelled to view certain of these species as components of a "drawdown flora" in Virginia, insofar as the floristic record appears to place such species exclusively within recently exposed substrates of permanent or semi-permanent water bodies during unpredictable drawdown conditions. Among these, we would include: *Lipocarpha micrantha*, *Oldenlandia boscii*, *Eragrostis hypnoides*, and *Paspalum dissectum*. Several other species appear capable of exploiting the habitat in a similar manner (see discussion below). However, such species are more widespread and common to different habitat types; therefore, these associated species do not appear to be unique to drawdown habitat in the context of this discussion.

Characteristics of the Drawdown Flora

In our study, all four dominants, including *Fimbristylis autumnalis*, *Lipocarpha micrantha*, *Oldenlandia boscii*, and *Eleocharis acicularis*, are characteristically small-seeded

Table 3. Dominant species at five-meter increments away from the original shoreline (original shoreline = 0 meters). State rare species are denoted in bold font. Dominant species were calculated as relative dominance (cover) across all three transects at each five meter increment

Distance (m)	Dominants (relative dominance)
0	*Oldenlandia uniflora* (0.48), *Fimbristylis autumnalis* (0.23)
5	*Fimbristylis autumnalis* (0.22), *Eragrostis hypnoides* (0.20), *Cyperus polystachyos* (0.15)
10	*Eleocharis acicularis* (0.35), ***Oldenlandia boscii*** (0.21)
15	***Lipocarpha micrantha*** (0.34), *Fibristylis autumnalis* (0.17), *Cyperus erythrorhizos* (0.17)
20	***Oldenlandia boscii*** (0.23), ***Lipocarpha micrantha*** (0.22), *Fimbristylis autumnalis* (0.12), *Cyperus polystachyos* (0.12)
25	*Cyperus polystachyos* (0.39), ***Lipocarpha micrantha*** (0.10)
30	***Lipocarpha micrantha*** (0.23), *Cyperus polystachyos* (0.23), *Cyperus echinatus* (0.23), ***Erigeron quercifolius*** (0.23)

species (Gleason and Cronquist 1991; Godfrey and Wooten 1979, 1981). In addition, they are typically diminutive plants, rarely exceeding 10 cm in height even during peak growing season. This is also true of several non-dominants in our plots, notably, *Oldenlandia uniflora*, *Eragrostis hypnoides*, *Paspalum dissectum*, *Juncus repens*, and *Hypericum mutilum*. All of the above-listed species were fruiting at the time of this study, and most individuals showed development of a dense inflorescence. This characteristic—marked by a diminutive, predominantly floriferous growth form—was also observed on some species that are normally not so minute in character, such as *Cyperus polystachyos* and *C. erythrorhizos* (Gleason and Cronquist 1991, Godfrey and Wooten 1979, Radford et al. 1968).

As Keddy and Constabel (1986) have noted, on sandy, coarse-grained lakeshore substrates, recruitment favors small-seeded species. This is because small seeds have a greater capacity to migrate into the moist pore interstices of the sediment, which increases the opportunity for germination under favorable conditions in contrast with larger seeded species. Further, small seed size tends to favor persistence in the seedbank (Thompson 2000, Murdoch and Ellis 1992, Leck 1989). This is an advantage that appears to be exploited by most of the species observed in our study.

The prolific nature of these plants—the ability to germinate under favorable conditions and immediately produce viable seed in large quantity—is presumably accommodated by five factors: (1) the small seeds are rapidly incorporated into the exposed sediment at seed set and, following inundation, remain near the sediment surface because the overlying water provides a relatively stable condition at the water-sediment interface (i.e., the seeds are not subject to burial due to mechanical forces as in terrestrial environments; Fenner 1985); (2) flooding works to inhibit germination between drawdowns, thus increasing seed persistence (Baskin et al. 1993); (3) flooding also results in an anoxic environment in the sediment, which reduces the risk of deterioration and increases seed longevity (Leck 1989); (4) the resultant ability of these species to perennate in the sediment seedbank for long periods of time results in a favorable condition for germination upon drawdown because the seeds are shallow in the sediment profile and thereby readily exposed to environmental germination cues such as light, temperature, and oxygen (Fenner 1985, Nicholson and Keddy 1983); and, (5) due to the stresses imposed by the unpredictable inundation-drawdown dynamic (Baskin et al. 2002), these species persist in a temporal niche that is nearly free from competition by other potentially aggressive colonizers.

Observations during a subsequent, drought-induced drawdown event in 2002 confirmed the persistence of these species at our study site. Based on the hydrographic data record, the reservoir water surface elevation dropped approximately 1.5 meters between May 2002 and February 2003, reaching its lowest level in mid-October 2002 (David Morris, pers. comm. 2005). Although the lake level did not recede far enough during this event to replicate the transects for a comparative evaluation, we noted that the dominants observed in 1998 were also present in 2002, and in the case of several species (e.g., *Lipocarpha micrantha*), cover and density appeared to have increased between drawdown events.

Zonation

Our similarity analyses could not discern any perceptible zonation patterns in the overall community with respect to distance from the original shoreline. As Figure 2 shows, the reservoir was pumped down over a relatively short time period, thus the sediments were not exposed differentially in time as would be expected during a climatic event (e.g., drought). As a result, the fluctuation of ambient water level within the reservoir at any point in time would not have exerted the same controlling force on species recruitment as noted in similar studies (Riis and Hawes 2002, Oldland and del Moral 2002).

However, when we analyzed dominance by distance class, it was apparent that certain species were more prevalent at certain distances from the original shoreline. In particular, *Fimbristylis autumnalis* appeared as a dominant within 20 meters of the shoreline, whereas two of the putative drawdown species (*Lipocarpha micrantha* and *Oldenlandia boscii*) were only dominant beyond the 10-meter line. We suspect that a principal dispersal vector for several of the species arriving to this site is wading avifauna (Fenner 1985). Birds bring small seeds to sites on mud-encrusted feathers and wings, and deposit these seeds in shallow portions of the reservoir while foraging for resources. If true, this raises an interesting question – if the seeds of different species arrived by the same mechanism, how are the dominants differentiated along the substrate?

In a germination study, Baskin et al. (1993) found that flooding treatments did not inhibit germination of *Fimbristylis autumnalis* seeds in a controlled-environment experiment. This suggests that under normal seasonal fluctuation, this species persists near the shoreline within the shallow reaches reservoir (ca. 0.5 m or shallower), exerting a competitive influence on the seedbank. If so, we suspect that during a more gradual drawdown event such as a drought, the waterline would fluctuate as it recedes, and as such, potentially flood-tolerant germinators like *Fimbristylis autumnalis* would exert a similar influence on the seedbank recruits. Therefore, it appears as though partial droughts (i.e., smaller, higher frequency drawdown events) favor *Fimbristylis autumnalis* along the perimeter of the reservoir, and more dramatic events like the Diascund Reservoir drawdown in 1998 are more conducive to colonization of the rare species noted in our study such as *Lipocarpha micrantha* and *Oldenlandia boscii*, which appear as dominants farther out along the exposed substrate.

Recommendations for Further Research

We suspect that the species we have identified as components of a drawdown flora in Virginia are present in the sediment seedbanks of similar water bodies within the region. The difficulty of studying such communities during an opportune drawdown event remains a research problem, because the stochasticity of such events precludes predictability. However, it should be possible to study the seedbank in a controlled environment by extracting sediment cores and conducting germination experiments accordingly (Nicholson and Keddy 1983). Future research on this subject would benefit immeasurably from seedbank assays performed in this manner.

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