J. Aquat. Plant Manage. 47: 151-155

Clonal Expansion of Cattail (*Typha domingensis*) in Everglades Stormwater Treatment Areas: Implications for Alternative Management Strategies

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INTRODUCTION

Expansion of cattail, *Typha domingensis*, is perhaps the most conspicuous indicator of long-term degradation of the Florida Everglades. The spread of cattail in the Everglades has been tracked at a landscape scale through photointerpretation of aerial and satellite photography (Rutchey and Vilchek 1994, Jensen et al. 1995, Rutchey and Vilchek 1999 and Rutchey et al. 2008) and has provided an impetus for observational and experimental investigations of the causes and implications of this alteration of the wetland plant community and associated habitat (Davis 1991, Urban et al. 1993, Doren et al. 1997, Newman et al 1998, Hagerthey et al. 2008). These studies indicate elevated phosphorous inputs from agricultural runoff have been a primary driver of cattail expansion and associated replacement of the natural sawgrass and slough communities of the Everglades system.

While expansive growth of *T. domingensis* is undesirable in the remnant Everglades (i.e., the Water Conservation Areas and Everglades National Park), this species is a vital component of stormwater treatment areas (STAs) that have been constructed to reduce the phosphorus inputs (Guardo et al. 1995) that have impacted the structure and function of the Everglades ecosystem. The STAs consist of compartmentalized flow ways with multiple cells ranging in size from 100-1400 ha, and currently are managed to support either emergent or submerged aquatic vegetation (Burns and McDonnell 2003). *Typha domingensis* is the dominant species in emergent cells, where it provides for phosphorus uptake and storage primarily through the production of leaf litter biomass. Phosphorus inputs are removed from the water column by microbial communities associated with the slow decomposition of this cattail leaf litter, which simultaneously accumulates in a soil building process that buries the stores of sequestered phosphorus (Kadlec 2006, Richardson et al. 1997).

Based on performance models and analyses (Burns and McDonnell 2003) the preferred configuration of Everglades STAs has emergent cells that discharge into cells with expansive beds of submerged aquatic vegetation (SAV). The SAV cells, which consist primarily of southern naiad, *Najas quadalupensis, Chara* spp. and pondweed, *Potamogeton illinoensis,* provide for phosphorus removal through direct uptake, an associated periphyton complex and by a coupled calcium coprecipitation/adsorption pathway (Dierberg et al. 2002b, Scinto and Reddy 2003). When positioned downstream of emergent cells that provide initial treatment of stormwater runoff with high P loads, SAV cells have the capability of reducing P concentrations to the low levels (Dierberg et al. 2002a, Knight et al. 2003) that are needed to achieve Everglades restoration goals (Davis and Ogden 1994). Establishment and maintenance of SAV cells has required frequent herbicide applications to control invasion by floating and emergent vegetation, including spread of *T. domingensis* from linear stands (emergent vegetation strips) that are maintained to buffer wind and wave energy, which can generate catastrophic disturbances to the SAV beds, particularly during tropical storm events.

The SAV cells of Everglades STAs have shown evidence of phosphorus removal efficiencies (Juston and DeBusk 2006) that are desired (i.e., outflows of ≈ 10 µg/L), but have characteristics that may compromise their sustainability. For example, due to the relatively rapid rates of decomposition (i.e., 10× faster than cattail) (Chimney and Pietro 2006) and the precipitation and deposition of calcium carbonate in SAV beds (Dierberg et al. 2002a,b), SAV cells accrete unstable, flocculent substrates that could eventually inhibit their ability to support growth of rooted SAV. Potential consolidation of these sediments is precluded by permanent inundation of SAV cells, which is needed to maintain SAV growth and to provide for sustained treatment of stormwater runoff. Alternative management strategies would allow for expanded growth of *T. domingensis* within SAV beds, or potentially in a managed rotation. Incursion of *T. domingensis* could help stabilize soils through more substantive root and rhizome growth and with the deposition of more recalcitrant (Osborne et al. 2007) and slowly decomposing leaf litter (Chimney and Pietro 2006). Thus, population growth characteristics of *T. domingensis,* including rates of expansion and associated attained densities, provide a basis for the formulation of management needs and potential alternatives for SAV cells of the Everglades STAs.

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The objective of this study was to quantify temporal rates of lateral expansion (distance from initial border and associated ramet densities) of extant stands of *T. domingensis* into adjacent beds of dense SAV. The scale of this study provides much finer resolution than previous landscape mapping efforts in the Everglades and addresses both routine and strategic vegetation management issues in the STAs.

METHODS

Expansion rates of *T. domingensis* stands were measured along three randomly located 5 m long permanent transects at 10 replicate sites along the outer edges of 30 m wide emergent vegetation strips in Cell 2B of STA 3/4 (Figure 1). During the three year period preceding this study, total phosphorus inflow concentrations for this SAV cell averaged 36 µg/L. The *T. domingensis* stands developed shortly after the cell was established in June 2004, and periodic herbicide applications maintained a distinct boundary between the emergent cattail and abutting beds of SAV, which are dominated by southern naiad (*Najas guadalupensis*). Suspension of herbicide applications allowed for clonal expansion of *T. domingensis* ramets into the SAV.

Expansion rates were measured at 5, 8 and 15 month intervals after transects were established in April 2007. During April 2007 and subsequent sampling periods the number of live *T. domingensis* ramets were counted in 1.0 m^2 quadrats at 1 m intervals along, and perpendicular to, each 5 m transect. The transects paralleled and thereby delimited the initial edge of the cattail stand and were marked with PVC poles. Sample means (n = 5 quadrats) along each 5 m transect were used to calculate transect means (n = 3) for each replicate site, which were averaged (n = 10) to provide temporal estimates of mean *T. domingensis* densities for each 1 m interval perpendicular to the initial boundary of the stand. This derivation of mean *T. domingensis* densities provides estimates of variability (standard errors) among sites, which were selected non-randomly but are representative of managed cattail stands in this and other

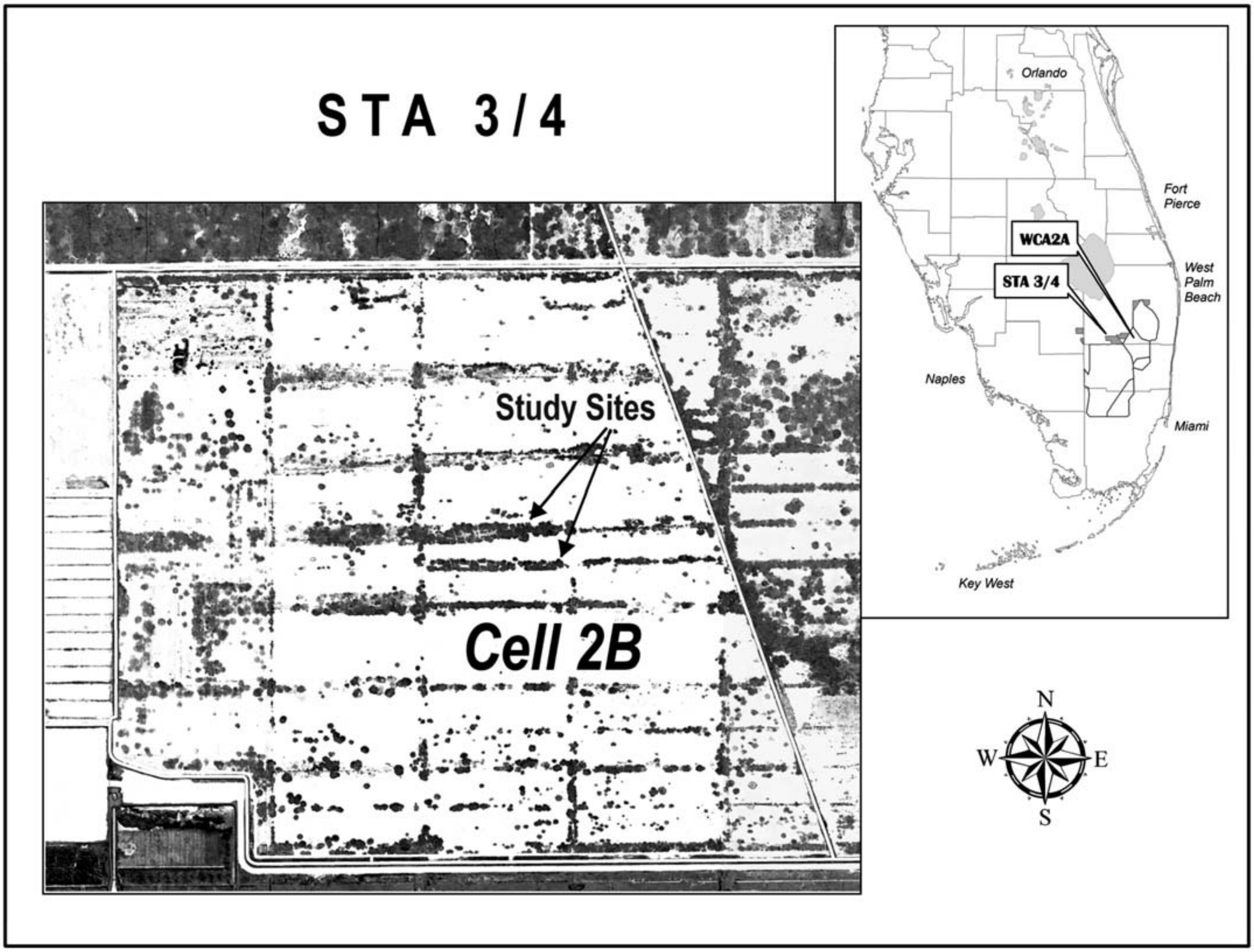

Figure 1. Locations of study sites along two linear emergent vegetation strips in the center of Cell 2B of STA 3/4. Location map shows the STAs (small shaded polygons) and adjoining the Everglades Water Conservation Areas.

STAs. A single factor ANOVA was used for comparisons of mean densities of *T. domingensis* ramets along the initial border and the perpendicular 1 m sampling intervals.

RESULTS AND DISCUSSION

During April 2007, the border of *T. domingensis* at sampled sites had an initial mean (± standard error) density of 5.7 ± 0.3 live ramets/m^2 with very little growth extending into the adjacent SAV beds (Figure 2). Over the next five months mean *T. domingensis* density along this initial border increased to 13.6 ± 1.0 live ramets/m^2. Densities along this bordering transect remained at similar levels through the next two sampling periods while the *T. domingensis* stand expanded into the adjacent SAV beds. Ramets were found 6 m from the original border after 5 months, expanded another two meters over the next 4 months and had colonized 13 m from the initial boundary after 15 months.

After 5 months, highest increases in *T. domingensis* density (9.2 live ramets/ m^2) occurred 1 m outside the original border. Thereafter, mean density at perpendicular sampling increments increased by 3.2-4.1 live ramets/m^2 at sampling locations 2 to 4 m from the initial boundary between 5 and 8 months and by 3.8-6.3 live ramets/m^2 at sampling increments 3 to 7 m from the original border transect between 8 and 15 months. By this last sampling period (i.e., 15 months after expansion began) *T. domingensis* had attained similar mean densities (p (F) = 0.47) from 1 m (10.3 ± 0.9 live ramets/m^2) to 6 m (6.7 ± 1.6 live ramets/m^2) adjacent to the initial border. These densities were not significantly different (p (F) = 0.10) than that attained along the initial border (12.6 ± 0.8 live ramets/m^2), and based on observations of remaining SAV growth did not appear to have reached a level where associated shading would eliminate SAV.

Measured rates of clonal expansion indicate extant stands of *T. domingensis* can readily colonize adjoining SAV

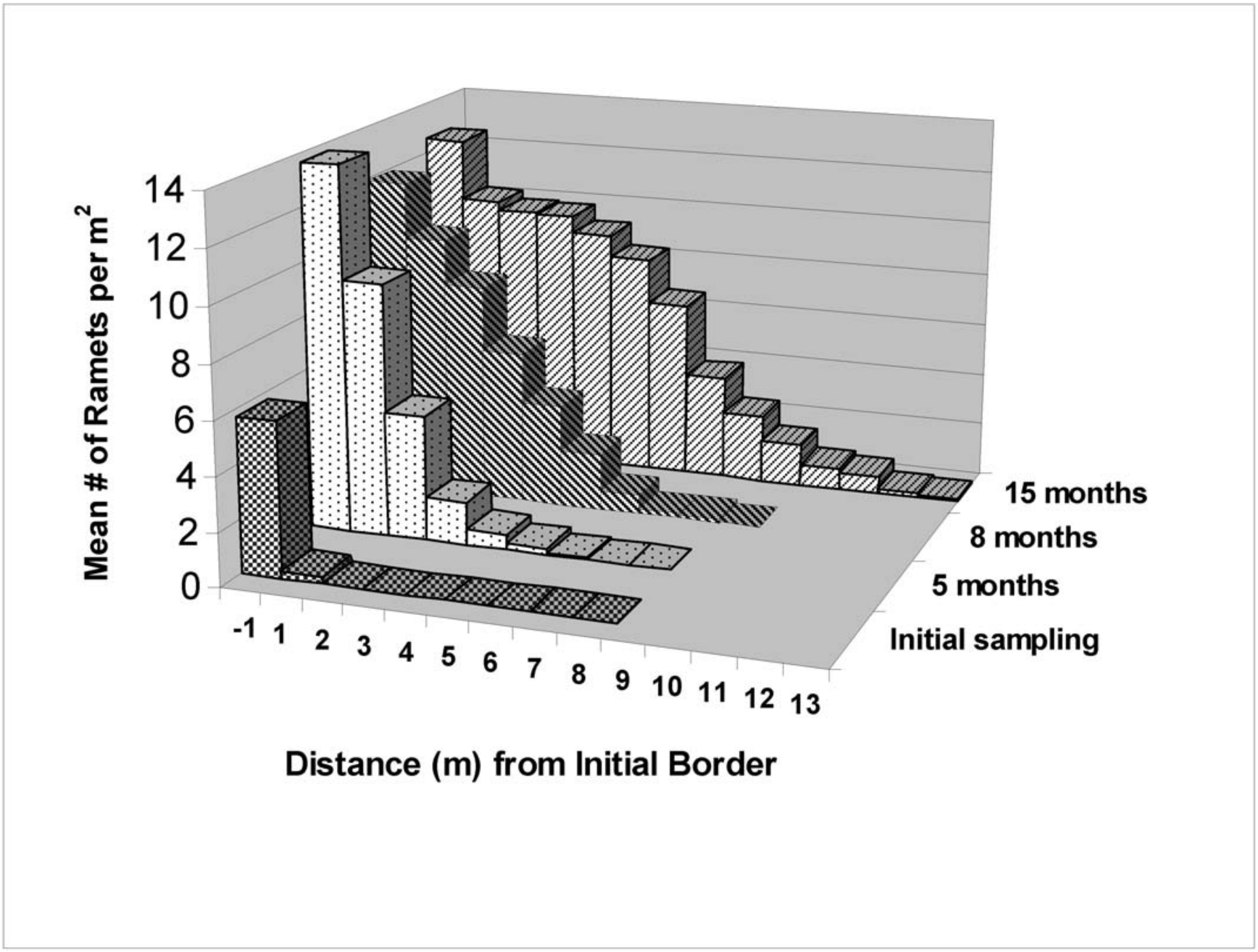

Figure 2. Clonal expansion of *T. domingensis*. Bar graphs show mean density of live *T. domingensis* ramets at 1 m sampling increments perpendicular to initial (April 2007) borders between the *Typha* stands and abutting beds of SAV. Sampling increments represent contiguous 1.0 m^2 quadrats from the initial border (i.e., the (0)-1 m increment) of the 5 m long transects.

beds. Temporal characteristics suggest continual spatial expansion of ramets into uncolonized portions of SAV beds with coincident, but slower increases in density. These characteristics reflect adaptive allocation of resources to rhizome growth and a strategy by which *T. domingensis* successfully invades phosphorus enriched sites in the remnant Everglades (Miao et al. 2000, Miao 2004). Maximum densities along the expansion front (≈ 12-13 live ramets/m^2) were comparable to densities of *T. domingensis* at sites in Water Conservation Area 2A (Figure 1) where surface water concentrations of total phosphorus were > 15 µg/L (Miao and Sklar 1998, Weisner and Miao 2004). Similar densities of *T. domingensis* also have been measured along the border of cattail stands in another STA (i.e., 15.1 ± 1.3 ramets/m^2 in STA 5, L.A. Toth, unpublished).

The observed rate of expansion of *T. domingensis* is indicative of the management efforts (i.e., herbicide applications) that are needed to control growth of emergent vegetation in SAV cells of STAs. These results also highlight the opportunity for implementing alternative management strategies that exploit the invasive growth characteristics of *T. domingensis* and its functional capabilities in phosphorus-rich wetlands. Infiltration of *T. domingensis* would change the structure (i.e., through enhanced root and rhizome architecture) and physical and chemical characteristics (e.g., bulk density, organic matter fiber content) of unstable, accreted soils in SAV beds, and provide an alternative phosphorus removal pathway (i.e., decomposing leaf litter). Multiple (even competing) nutrient uptake pathways could help ensure the sustainability of STAs by providing a functional (i.e., P removal) redundancy that confers resilience to potential disturbances (Brookes et al. 2005) such as herbivory, drought, tropical storms, and prolonged deep water events. Although results of this study indicate SAV beds remained within the infiltration front for over one year after encroachment of *T. domingensis* was allowed, management intervention (i.e., herbicide treatments) would eventually be required to prevent growth and associated accumulation of *T. domingensis* leaf litter from restricting light penetration needed for maintenance of functional beds of SAV. Innovative herbicide application strategies for maintaining mixed growth of SAV and *T. domingensis* in STAs require insightful timing and selective measures for thinning stands of *T. domingensis*, and are currently being evaluated. Alternatively, measured rates of clonal expansion of *T. domingensis* could be used to manage for planned rotations of stands of *T. domingensis* and beds of SAV (e.g., like agricultural crops). Ongoing complementary studies of treated stands of *T. domingensis* will evaluate the feasibility of such rotations by evaluating rates of SAV establishment on dead cattail litter. Toth (2007) found SAV colonization of treated torpedograss was delayed until the accumulated thatch was partially decomposed and fully submerged.

ACKNOWLEDGEMENTS

We thank Shili Miao, Sue Newman, LeRoy Rodgers and anonymous reviewers for helpful comments on the draft manuscript and Terri Bennett for constructing Figure 1.

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