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The Management and Ecology of the Wetland Grass, Maidencane

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ABSTRACT

We provide a comprehensive ecological profile of the wetland grass maidencane, or paille fine (*Panicum hemitomon* J.A. Schultes), for improved wetland management. This species has direct application for wetland restoration due to its ability to improve water quality and ameliorate contaminated soils, in addition to providing valuable wildlife habitat. It is a warm season, perennial grass native to freshwater wetlands throughout the southeastern United States, commonly occurring on coastal plain soils. Its dominance of some wetland sites can be attributed to its tolerance of wide ranges in edaphic and environmental gradients, including a tolerance for extended flooding or frequent fire. It reproduces clonally, with no evidence of seed viability. It is aggressive on some sites and forms dense, monotypic stands, but it is also associated with diverse emergent plant communities, which comprise other grasses, sedges, rushes, and bryophytes. Its habit of prolific root growth contributes to soil stabilization, peat formation, and nutrient immobilization. Maidencane also provides valuable refuge, nesting, and feeding habitat for myriad wildlife species. For wetland restoration projects requiring rapid colonization, perennial persistence, and tolerance of multiple environmental gradients, maidencane should be considered a candidate among high performance species.

Key words: freshwater wetland, maidencane, *Panicum hemitomon*, wetland restoration.

TAXONOMY

The wetland grass maidencane (*Panicum hemitomon* J.A. Schultes) is in the tribe Paniceae, subfamily Panicoideae, and family Poaceae. Worldwide there are about 500 species of *Panicum*, which are mostly tropical, but they also extend into the temperate zones of both hemispheres (Webster 1988). In the contiguous United States, the genus *Panicum* comprises more than 30 species (most are concentrated in the southeastern U.S.); 25 are native and seven are considered established introductions (Freckmann and LeLong 2006).

The identification of *P. hemitomon* is most often confused with three other grasses described by Tobe et al. (1998): cup- or bag-scale grass (*Sacciolepis striata*), which is decumbent at the base and usually has purple margins at the top of the sheath and the bases of some blades; blue maidencane (*Amphicarpum muhlenbergianum*), which is generally much shorter and has stiff leaves with an almost translucent or purple margin; and para grass (*Brachiaria mutica;* synonymy *Urochloa mutica*), with stems decumbent at the base, somewhat swollen nodes, and hairy sheaths and leaf bases. *P. hemitomon* var. *hirsutior* has purplish lower stems and short, stiff hairs on the stem bases. Line drawings and photographs for comparison of these species are available through the Center for Aquatic and Invasive Plants, Institute of Food and Agricultural Sciences, University of Florida and the NRCS PLANTS database (Figure 1). Radford et al. (1964) give the following detailed description for *P. hemitomon*:

> Culms 6-8 dm tall, nodes and internodes glabrous. Leaves cauline; blades to 3 dm long and 15 mm wide, glabrous or sparsely papillose-pilose on both surfaces, margins smoothish; sheaths glabrous to sparsely papillose-pilose or hirsute; ligules membranous and ciliate or lacerate, 0.5-1 mm long. Panicle constricted, 15-25 cm long, 3-16 mm broad; branches ascending, scaberulous. Spikelets 2.4-2.7 mm long; pedicels scaberulous, 0.5-6 mm long. First glume 3-nerved, glabrous, margins scarious, acute to cuspidate, 1.2-2 mm long, 2nd glume 5-nerved, glabrous, margins scarious, acute, 2.2-2.5 mm long, sterile lemma 3-nerved, glabrous, margins scarious, acute, 2.2-2.5 mm long, sterile palea scarious, 2 mm long; fertile lemma and palea faintly nerved, lustrous, yellowish, acute, 2.2 mm long.

Characteristics of roots, nodes, and internodes of the genus *Panicum* are variable and considered of little diagnostic use (Webster 1988). Brown (1948) reported a chromosome number of $2n = 36$ from cells collected in root tips. *P. hemitomon* is a C_3 plant based on its carbon isotope fractionation ($\delta^{13}C = -25.2$, Smith and Brown 1973; $\delta^{13}C = -25.7 \pm 0.1$, Kirkman and Sharitz 1993). A comparison of epidermal palea characteristics among the genera *Dicanthelium*, *Panicum*, and *Echinochloa*, showed that *P. hemitomon* exhibited unusual epidermal features; no papillae were present but there were spicules and numerous four-lobed silica cells (Clark and Gould 1975).

GENERAL CHARACTERISTICS, GEOGRAPHIC DISTRIBUTION, AND HABITAT-ASSEMBLAGES

Panicum hemitomon typically has an erect growth habit, but its culms will also creep laterally into open water. Adventitious rooting is common at culm nodes that are inundated (Lessmann et al. 1997, Clark and Reddy 1998, Dowty 1998, Pahl 2002, Willis and Hester 2004). The net aerial primary productivity of *P. hemitomon* in natural communities ranges from <150 g m^{-2} y^{1} (Schalles and Shure 1989) to >1,350 g m^{-2} y^{1} (Sasser and Gosselink 1984). Within a wetland site, it may

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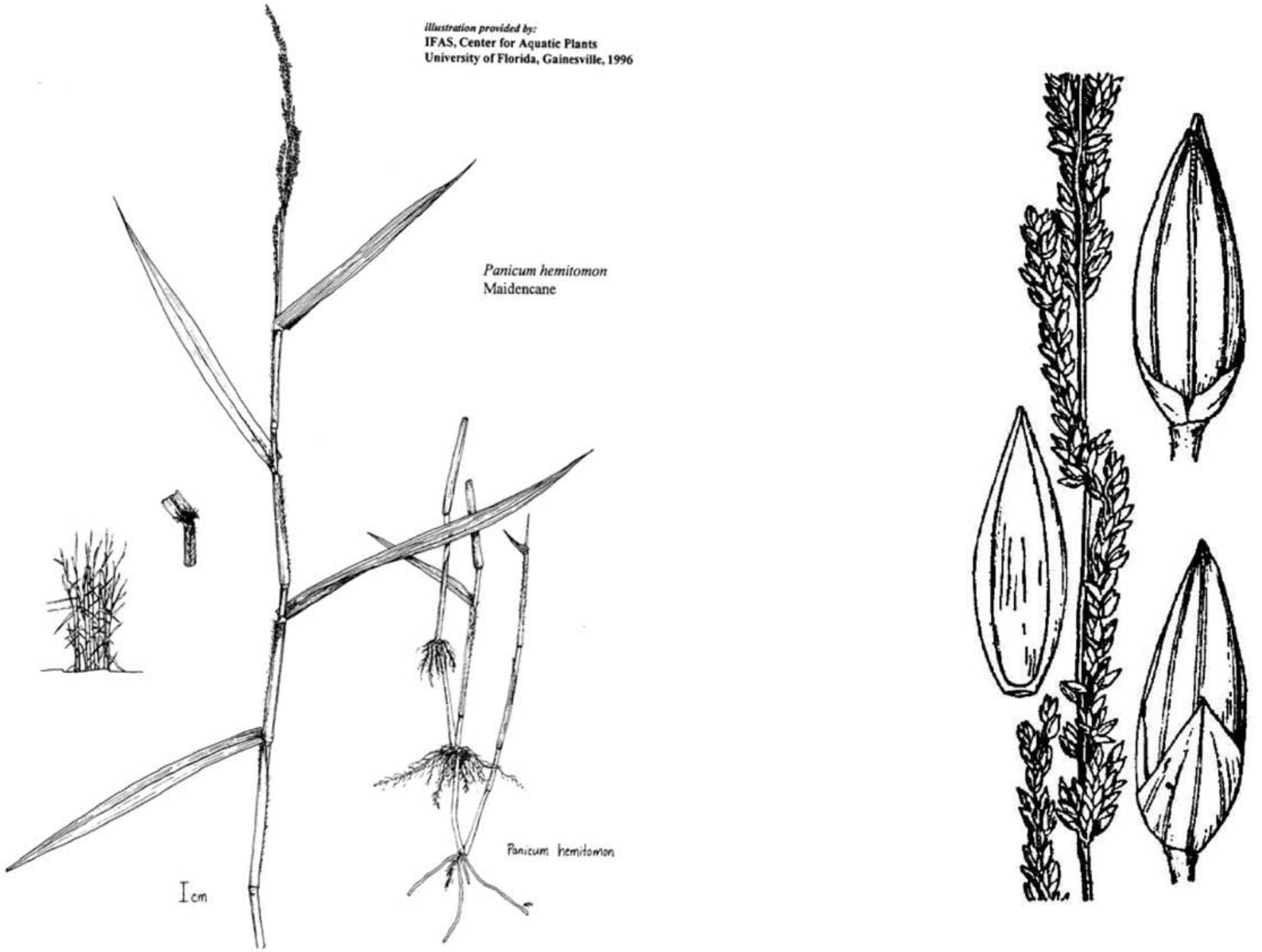

Figure 1. *Panicum hemitomon*: its growth habit, inflorescence, and spikelets. Line drawings courtesy of IFAS Center for Aquatic Plants, Univ. of Florida, Gainesville, and Texas Agriculture and Mechanical University, College Station, Texas.

have a comparable standing crop (1,075 g m^{-2}) to other dominant freshwater plants, such as *Typha domingensis* (1,480 g m^{-2}) and *Schoenoplectus validus* (1,380 g m^{-2}; Polisini and Boyd 1972). In its subtropical range, it grows about 280 days per year (Sasser and Gosselink 1984).

P. hemitomon ranges from New Jersey south to Florida then west to Texas, and it is found in Arkansas and Tennessee (Freckmann and LeLong 2006). *P. hemitomon* is common to the wetland landscapes of the Florida Everglades (Loveless 1959, Kushlan 1990, Daoust and Childers 1999), the Okefenokee Swamp (Cypert 1972, Duever 1982), and Carolina Bays or depression wetlands (Kirkman and Sharitz 1993, Miller and Bever 1999, De Steven and Toner 2004, Mulhouse et al. 2005). In Louisiana, it is the dominant plant of most freshwater marshes in both the delta (O'Neil 1949, Sasser et al. 1995a) and chenier plains (Williams 1951, Evers et al. 1998, Holm et al. 2003a), but it is absent from newly formed deltaic sediments (Chabreck and Palmisano 1973, Shaffer et al. 1992).

In Florida's lakes, floodplains, and the Everglades, *P. hemitomon* is associated with a 'wet prairie' community type (Loveless 1959), which comprises spike rushes (*Eleocharis* spp.), nymphaeids (*Nymphaea*, *Nymphoides*), grasses (*Paspalidium*), beak rushes (*Rhynchospora* spp.), arrowheads (*Sagittaria* spp.), pickerelweeds (*Pontederia* spp.), lilies (*Crinum*, *Hymenocallis*) and bladderworts (*Utricularia* spp.; Wade et al. 1980, Lowe 1986, Wood and Tanner 1990). In coastal plain depression wetlands and Carolina Bays, it is associated with the perennial graminoids, *Carex striata* and *Leersia hexandra,* in addition to *Sphagnum* spp., *Cephalanthus occidentalis*, *Nyssa biflora*, *Eleocharis* spp., *Rhexia* spp., and nymphaieds (*Nymphaea odorata* and *Brasenia schreberi*; Schalles and Shure 1989, DeSteven and Toner 2004, Mulhouse et al. 2005).

In Louisiana's chenier plain, it forms dense, nearly monotypic stands on sites with extended hydroperiods (Evers et al. 1998, Holm et al. 2003a); however, on the floating marshes of the delta plain it grows in diverse assemblages that support more than 55 species, including orchids (*Calapogon* and *Ha-*

beneria), wildflowers (*Asclepias* and *Lobelia*), and bryophytes (liverworts and sphagnum mosses; Sasser et al. 1995b, Visser et al. 1998). One-quarter of 116 floating islands (tussocks) on Florida's Orange Lake contained maidencane. On these 'grass-type' floating islands, Mallison et al. (2001) found the following co-occurring genera in order of their abundance: *Hydrocotyle*, *Panicum*, *Typha*, *Polygonum*, *Bidens*, *Sacciolepis*, *Schoenoplectus*, *Limnobium*, *Pontederia*, and *Ludwigia*.

In a 6,400-ha rain-fed waterfowl impoundment (Lacassine National Wildlife Refuge, Louisiana), *P. hemitomon* is the dominant emergent plant of higher elevations and extends into a lower 'wet prairie' community with *Eleocharis equisetoides* and several nymphaeids (*Brasenia*, *Nelumbo*, *Nuphar*, *Nymphaea*; Fruge 1974, Holm et al. 2003a, Bass 2003, Howard 2005). Although it prefers full sunlight, *P. hemitomon* may occupy margins or the understory of *Taxodium* spp. bayheads and domes (Monk and Brown 1965, Ewel 1984, Gunderson 1984).

REPRODUCTION

Panicum hemitomon apparently relies entirely on vegetative growth from rhizomes and culm nodes for reproduction, and it can laterally spread 60 to 75 cm per growing season (Goudelock 1974). Kirkman and Sharitz (1994) found that its persistence following burning or tilling was due to vegetative reproduction rather than seed germination. Seed viability was considered nonexistent by Pfaff and Maura (2000); however, it was recorded as a 'seed bank species' in a Carolina Bay by Poiani and Dixon (1995). Seed production has been observed under inundated conditions in the field (Loveless 1959, Kirkman and Sharitz 1993). Kirkman and Sharitz 1993 did not observe seed production among different inundation treatments (moist, saturated, inundated, inundated-moist). Patton and Judd (1988) described the phenology of a natural stand of *P. hemitomon* in Alachua County, Florida, where flowering occurred from early to mid-June, and fruit dispersal occurred thereafter into July. In Louisiana, flowering occurs from middle-to-late April continuing throughout May (Guerry Holm, pers. observ.). We have found no information on experimental trials of seed viability or ecotypic variation in seed production.

GROWTH FACTORS

Sediment Type and Nutrition

Panicum hemitomon will grow on either organic or mineral substrates (Williams 1951, Shiflet 1963, Monk and Brown 1965, Dowty et al. 2001, Willis and Hester 2004). Greenhouse manipulations of soil type with *P. hemitomon* have shown that aboveground growth is greater in mineral (silt and clay) than highly organic soils (Dowty et al. 2001, Willis and Hester 2004). Natural stands are frequently found on peat-based soils (Wade et al. 1980, Lowe 1986, Kirkman and Sharitz 1994) and floating peat masses (Metzen 1977 in Newsom et al. 1987, Sasser et al. 1996). Dense stands occur on sandy, acidic (pH 5.8) soils of moist pastures in Florida (Kalmbacher and Martin 1988). Sandy soils subject to drying reduce stand height (Tobe et al. 1998). Birkenholtz (1963) reported *P. hemitomon* growing on entirely sandy soils in Florida's Paynes Prairie. Higher production and accumulation of maidencane litter in semi-native wetlands compared to improved pasture wetlands contributes to increased soil carbon to nutrient ratios (Gathumbi et al. 2005).

Acidic soil conditions (mean pH = 4.6 ± 0.3, range = 3.9-5.2) were associated with *P. hemitomon* at several Carolina Bays (Miller 2000). At these sites, total soil carbon and nitrogen (N) was 4.2 and 0.35%, respectively. Carolina Bays are considered nutrient poor, so the symbiosis of arbuscular myccorhizal fungi with *P. hemitomon* roots likely improves plant phosphorus (P) nutrition (Miller and Bever 1999, Miller 2000, Miller and Sharitz 2000). In the Everglades, maidencane tissue nutrient concentrations (molar N:P = 50) indicated that phosphorus availability may limit its abundance (Daoust and Childers 1999). Six coastal Louisiana populations of *P. hemitomon* showed a range of N:P ratios, which indicated both N or P may limit its productivity in these areas (Holm 2006). Although most of the Louisiana populations occupied sites that indicated N-limitation, a rain-fed impoundment showed P-limitation (Holm 2006). This species has a high resorption efficiency of nutrients, capable of retranslocation or withdrawal of 67 and 88% of N and P, respectively, from live tissue during leaf senescence (Holm 2006).

Sasser et al. (1991) conducted a seasonal and spatial nutrient study of a maidencane-dominated floating marsh in Louisiana that formed the transition between a swamp and lake. They found that N and P concentrations in the marsh peat and water beneath the mat were consistently higher than those of the surrounding lake and swamp. They hypothesized that the marsh served as both a sink and source of nutrients to the lake and swamp depending on the seasonal evapotranspiration and precipitation.

Fire

Walsh (1994) presents a comprehensive literature review on fire and *P. hemitomon*. It is common to wetlands experiencing frequent fires; its architecture—erect culms with numerous leaves, which persist on the culms throughout the dormant or dry season—facilitates high flammability (Cypert 1972, Vogl 1973, Wade et al. 1980, Lowe 1986, Kirkman and Sharitz 1994). In addition to the leaves, culms are also combustible with a slow or high intensity fire and low water levels (Figure 2). Fire in the winter or early spring promotes rapid re-sprouting of tillers within a few days (Loveless 1959) and a more productive stand (Vogl 1973). Increased sunlight, available nutrients from ash deposition, and soil insolation associated with fire may explain the higher productivity in burned compared to unburned stands (Wilbur and Christensen 1983).

In a study in northeast Florida, Lowe (1986) hypothesized that although hydrology is important in controlling the landscape distribution of *P. hemitomon* and *C. jamaicense* at some locations, fire alters competitive interactions between the two species through the following mechanism: "maidencane, and its associated species, rapidly colonize areas where dense stands of sawgrass [are] destroyed by intense fire and then inhibit the establishment of sawgrass seedlings. Sawgrass reclaims these areas through vegetative reproduction as a slowly moving front which monopolizes space and light."

Figure 2. Maidencane facilitates fire (top left). Depending on the intensity of fire, remaining culms provide ventilation to newly emerging tillers (top right). Plant death occurs if the stubble is completely removed and the stand flooded for a lengthy period. Although maidencane forms dense monotypic stands on sites with extended hydroperiods, it also coexists with bryophytes, sedges, ferns, and other grasses on floating marshes or peat batteries (*Sphagnum* spp. bed, lower left). On continually inundated sites, maidencane is a significant contributor to peat production and soil building (lower right).

Since rhizome growth controls the regeneration of *P. hemitomon*, severe peat burns conceivably may reduce its reestablishment (Sipple 1979, in Walsh 1994). Fire exclusion results in woody plant invasion and subsequent decreased herbaceous plant dominance (Huffman and Blanchard 1991), and fire exclusion on floating marshes in Louisiana has resulted in increased dominance of wax myrtle (*Myrica cerifera*; Williamson et al. 1984). No published reports could be found on the effects of burning during summer on maidencane survival and regrowth.

Flooding

Maidencane tolerates a broad range of flooding, from deep, continual inundation to relatively dry conditions (Schalles and Shure 1989, Kirkman and Sharitz 1994, Miller 2000), and there is some ecotypic differentiation to flood stress (Lessmann et al. 1997). At Dupuis Reserve in Florida, David (1999) reported the expansion of *P. hemitomon* coverage following increased inundation; its optimum range of flooding depths was 30 to 60 cm, but it also occurred in depths up to 80 cm. Loveless (1959) noted that it can grow in 1.0 m water depth for up to nine months. In the Okefenokee Swamp, sites containing *P. hemitomon* had a range of water level fluctuation of 40 cm above the soil surface (Duever 1982). During drought conditions, *P. hemitomon* can expand into previously open water sites in Carolina Bays (Mulhouse et al. 2005).

Flooding under greenhouse conditions stimulates aboveground biomass production of *P. hemitomon* (Kirkman and Sharitz 1993, Lessmann et al. 1997, Willis and Hester 2004). Under field conditions in Florida, it produced a maximum biomass with an inundation frequency of 85 to 90% (Lowe 1986). A 30 to 40 cm flooding depth was optimal for biomass production in a Carolina Bay (Schalles and Shure 1989). Increased biomass production with flooding may be explained by the culm elongation traits of maidencane. For example, Kirkman and Sharitz (1993) found that culm length was positively related ($r^2 = 0.78$) to water depth above the soil with approximately a 1:1 cm relationship; the range of water depth exceeded 1.0 m. Stem emergence, however, is significantly decreased when flooding occurs after culm removal (Kirkman and Sharitz 1993); apparently the erect, dead culms of maidencane may be critical for maintaining ventilation to roots and emerging tillers (Jordan and Whigham 1988). *P. hemitomon* produces adventitious roots at culm nodes following inundation, and these roots may be important for nutrient uptake (Clark and Reddy 1998, Dowty 1998, Pahl 2002, Willis and Hester 2004) and improved flood tolerance (Lessmann et al. 1997).

Grazing

Maidencane is an important range grass in Florida (Kalmbacher and Martin 1988) and Louisiana (Williams 1951), where it produces a high-yield, palatable forage for livestock (Kalmbacher 1983, Long et al. 1986). Pure stands of maidencane on cattle range in Florida produce between 4,000 and 6,000 kg ha^{-1} of dry aboveground matter (Kalmbacher and Martin 1988, Kalmbacher 1990). In a defoliation and fertilization study, it was tolerant of simulated grazing intervals greater than six weeks, and fertilization improved yield. However, frequent defoliation at three week intervals was especially detrimental to yield and tiller density (Kalmbacher and Martin 1988). With frequent livestock grazing, less palatable species such as *Juncus effusus* replaces maidencane on pasture wetlands in southern Florida, near Lake Okeechobee.

Under greenhouse conditions, aboveground biomass production is optimal at a clipping interval of six to eight weeks (Holm and Sasser 2006). The combined effects of culm removal followed by flooding may result in reduced tiller and culm production (Kirkman and Sharitz 1993).

Salt Tolerance

P. hemitomon has poor salt tolerance. Willis and Hester (2004) conducted a greenhouse study to test the growth response of *P. hemitomon* to low level salinity (0, 1.5, and 3.0 mg l^{-1}), flooding (0, 10, 20 cm), and soil type (high or low organic). Both elevated salinity treatments significantly reduced production over the eight-week study. Several other studies have found that *P. hemitomon* exhibits poor salt tolerance (Howard and Mendelssohn 1999a, b, LaPeyre et al. 2001) and recovery following salt exposure (Flynn et al. 1995). However, some genotypic variation in salt tolerance has been identified in greenhouse trials (Hester et al. 1998). Other studies have elucidated the relative importance of salt and sulfide, singly and combined, in affecting the growth and physiology of *P. hemitomon* (Pezeshki et al. 1987, Koch and Mendelssohn 1989, Koch et al. 1990, Pezeshki et al. 1991, Pahl 2002). Apparently, it lacks the anatomical and physiological characteristics to tolerate elevated or long-term salt exposure (McKee and Mendelssohn 1989). The field distribution of *P. hemitomon* in Louisiana is restricted to areas protected from frequent or intense exposure to saltwater (Penfound and Hathaway 1938, Shiflet 1963, Chabreck and Linscombe 1982).

USES FOR SOIL AND WATER REMEDIATION

Since it spreads rapidly below and above the waterline and creates a dense network of fine roots, maidencane has been recognized for its ability to control erosion along shorelines of lakes and ponds (Goudelock 1974, Bown 1975, Whitten 1998, Sistani and Mays 2001). It is not suitable, however, for stabilizing gullies in Florida's panhandle (NRCS 2000). The root and rhizome growth of maidencane enhances soil strength and belowground biomass of floating peat mats dominated by *Eleocharis baldwinii* (Sasser et al. 2004).

A positive growth response to nutrient enrichment has been observed under experimental settings (Schwartz and Boyd 1995, Hubbard et al. 1998) and short-term field experiments (Kalmbacher 1983, DeLaune et al. 1986). Stem numbers doubled with an application of 5 g m^{-2} of nitrogen in a greenhouse experiment (Sistani and Mays 2001). In a Louisiana freshwater marsh, aboveground biomass was increased 40% with the application of 10 g m^{-2} of NH_4-N, but at the dosage of 3 g m^{-2} NH_4-N, no appreciable differences were detected (DeLaune et al. 1986). Soils associated with natural stands of *P. hemitomon* in Louisiana were shown to remove large inputs of inorganic nitrogen through denitrification (Lindau and DeLaune 1991).

P. hemitomon has been used in the treatment of different wastewater effluents, including the treatment of catfish pond effluent where biomass production ranged from 4,780 to 1,870 g m^{-2} along an 80-m effluent gradient (80 to 0 m from effluent discharge, respectively). The shoot-to-root ratios changed from 1:1 to 1:3.5, indicating that aboveground growth is stimulated with increasing nutrient availability (Schwartz and Boyd 1995). In trials with swine lagoon effluent, it was useful in removing nitrogen when planted as riparian buffer strips (Hubbard et al. 1995, 1998, Entry et al. 2000). In another experiment involving swine lagoon effluent, Hubbard et al. (2004) found that *P. hemitomon* could be grown on floating-mat structures to remove nutrients. While *Juncus effusus* died in this experiment, *Typha angustifolia* and *P. hemitomon* produced 16,500 and 9,700 g m^{-2} of biomass, respectively.

P. hemitomon growth was tested on coal mine spoil deposits and compared to *Pontederia*, *Typha*, and *Schoenoplectus validus* (Sistani et al. 1998). *Pontederia* had the greatest vegetative expansion followed by *P. hemitomon*, and *S. validus*; *Typha* spread was irregular. In Florida, *P. hemitomon* has been used to remove nutrients from municipal effluents (spray fields) and to stabilize phosphate mine spoil deposits (Janet Grabowski, pers. comm.; NRCS 2001).

After a crude-oil spill in a freshwater floating marsh in Louisiana, *P. hemitomon* was transplanted in high concentrations of total petroleum hydrocarbons (80 g kg^{-1} soil). After five months, culm numbers increased by a factor of 3.2 (nonfertilized) and 4.8 (fertilized); *Sagittaria lancifolia* increased by a factor of 1.5 (Holm et al. 2003b; Figure 3). Greenhouse studies have confirmed a similar positive growth response of maidencane with crude-oil exposure (Dowty et al 2001).

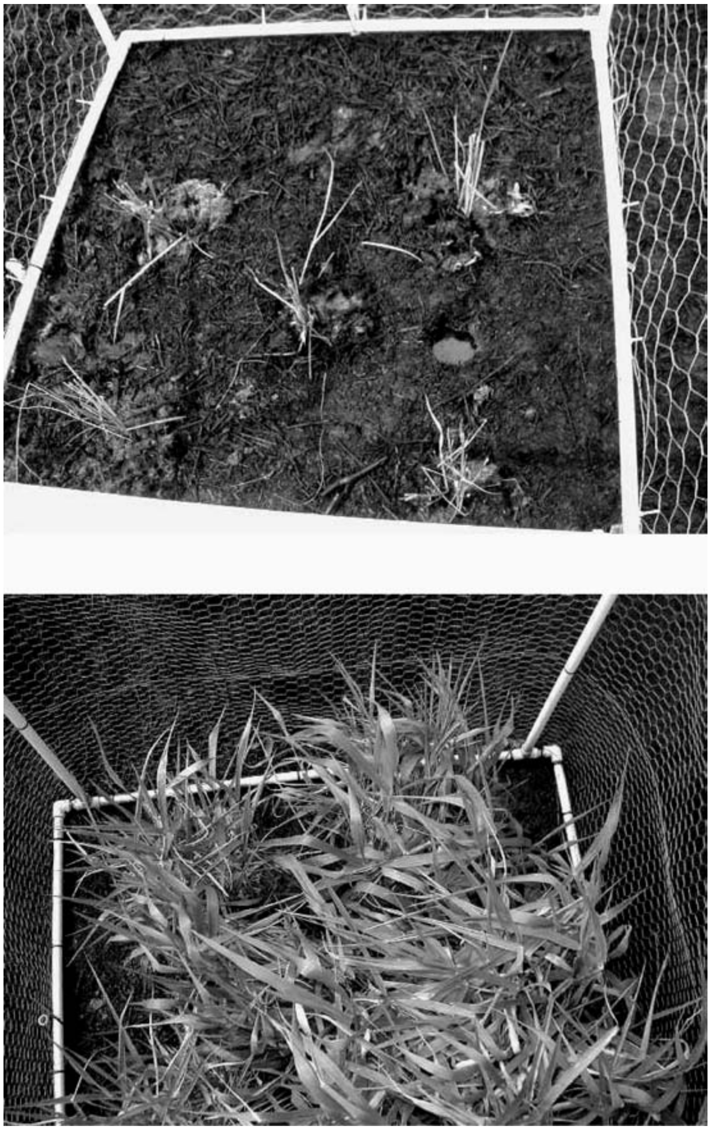

Figure 3. Maidencane can accelerate the recovery process of contaminated soils. In this case, crude oil was trapped in the peat matrix and physical removal was not feasible; furthermore, natural plant colonization was practically non-existent. Five clipped sods of maidencane from a donor marsh were transplanted into the oiled saturated peat (upper). Culm density increased by almost a factor of five after five months of growth (lower; Holm et al. 2003b).

WILDLIFE HABITAT USE AND VALUE

Vogl (1973) conducted a study on the wildlife use of maidencane habitats and the effects of burning. The usage of the burned habitat compared to unburned was consistently greater for 'resident,' 'transient,' and 'occasional' bird species. Small mammals, reptiles, and amphibians also used both the burned and unburned areas, but alligators used the burned sites almost exclusively. Results of the study were not attributed to improved visibility in the burned areas because burned areas became more densely vegetated upon regrowth.

Shallowly flooded maidencane, associated with spike rush (*Eleocharis cellulosa*), is important habitat for apple snails (*Pomacea paludosa*), which comprise the chief food of the endangered Everglade snail kite (*Rostrhamus sociabilis*; Bennetts et al. 2002). The endangered Florida sandhill crane prefers maidencane as a nest substrate in both the Okefenokee Swamp (Bennett 1989) and the Everglades (Thompson 1970). Another species of concern in Florida, the round-tailed muskrat (*Neofiber alleni*), uses *P. hemitomon* as nest material and a food source in shallowly flooded wet prairies (Birkenholtz 1963). Wood storks (*Mycteria americana*) feed in wet prairie communities with maidencane (Kahl 1964). The fulvous whistling-duck (*Dendrocygna bicolor*) uses maidencane marshes for nesting (Hohman and Lee 2001).

In the Okefenokee Swamp, batteries of floating peat dominated by *P. hemitomon* were selected as nesting habitat for the American Alligator (*Alligator mississippiensis*; Metzen 1977 in Newsom et al. 1987). Maidencane-dominated floating marshes in Louisiana support a high density (0.53 nests ha^{-1}, 14-yr mean; Visser et al. 1999) of alligator nests compared to a regional mean (0.02 nests ha^{-1}; McNease et al. 1994).

Depending on water level fluctuations, wet prairies are important refuges for invertebrates and small fish (Kushlan 1976, DuRant et al. 1979). Largemouth bass (*Micropterus salmoides*) use maidencane for nesting substrate in the absence of inorganic substrates (Bruno et al. 1990 in Walsh 1994). Maidencane may compete with food plants desirable to waterfowl (Lynch et al. 1947).

PLANTING AND MANAGEMENT

Ecotypes

U.S. Department of Agriculture/NRCS Plant Materials Centers (PMC) have released two ecotypes or cultivars of *P. hemitomon*. 'Halifax' was released by the Coffeeville, Miss, PMC in 1974 and was selected based on its cold tolerance, rapid spread, and vigorous growth. None of the seed was found to be viable (Whitten 1998). The only other release was 'Citrus Germplasm' in 1998 from the Brooksville, Florida, PMC. Citrus was selected based on uniform spread and high productivity in a sub- to tropical climate (Janet Grabowski, pers. comm., NRCS, Brooksville, FL). Similar to Halifax, Citrus produces nonviable seed. Trials in Florida showed that Citrus out-produced the Halifax ecotype (NRCS 2001). No ecotypes have been released from the Louisiana deltaic or chenier plains despite its abundance in these habitats.

Propagation and Field Establishment

With no evidence of seed viability, vegetative propagation is required. Maidencane can be propagated from new tillers, mature culms, and inter-node pieces under warm conditions and full sunlight. Freshly-clipped, mature culms can be placed in shallow water and new culms and adventitious roots will sprout from the nodes. The plants are easily started in this manner, but extended hydroponic growth requires close attention to nutrient levels to avoid limitation (Guerry Holm, pers. observ.). Milled peat is a good growth substrate combined with a timed-release fertilizer that ideally contains macro- and micronutrients; fertilizer should be applied at 'low' rates given the sensitivity of *P. hemitomon* to salt. Pezeshki et al. (2000) grew maidencane in peat media and used water-soluble fertilizer (20-20-20, % N-P-K) at a concentration of 1.25 g l^{-1}. Different combinations of fertilizer N and P have not been tested for optimal growth response; however, shoot and root production of maidencane is increased with fertilization compared to peat alone (Pezeshki et al. 2000).

Bare-root plants or rhizomes are used to establish stands of maidencane in the field. For pond or water impoundment levees, rows of bare-root plants should begin about 1 ft above the normal water line and continue upslope with 1-ft spacing between the rows and individual plants. Rhizomes can be planted in furrows 2 to 6 inches deep (Whitten 1998, NRCS 2001). Citrus maidencane was planted on phosphate mine spoil in Florida in early October with a Bermuda grass sprig-planter at a rate of 40 bushels of rhizomes per acre (NRCS 2001). At a different site in Florida, hand planting of rhizomes in July (25 bushels per half acre) resulted in a solid stand of Citrus maidencane within six months (NRCS 2001).

In Louisiana, *P. hemitomon* was hand transplanted from a donor marsh into degraded peat-based floating marshes dominated by *Eleocharis baldwinii* (Sasser et al. 2004). The objective of the study was to test the feasibility of large-scale restoration of this heavily grazed (nutria) marsh type. Maidencane did not survive in unprotected plots; however, transplants in protected plots resulted in an almost complete coverage of 16 m^2 plots within three growing seasons. Although fertilization of protected maidencane improved coverage in the first growing season, at the end of three growing seasons, aboveground and belowground biomass was similar between the fertilized and nonfertilized treatments.

Methods of Control

In some habitats, *P. hemitomon* may need to be controlled to prevent it from taking over other desirable submersed or emergent plants. Although physical removal of maidencane in the floating tussock form has been done (Mallison et al. 2001), chemical control is most feasible. Glyphosate (Rodeo® Monsanto Agricultural Co., St. Louis, MO) is a foliar herbicide recommended for immersed wetland plant control. Thayer et al. 1986 suggested use of Rodeo® for partial control of *P. hemitomon* in Florida ponds. Fosman (2000) found that 0.25% Rodeo® resulted in 50% tissue damage to *P. hemitomon*; higher rates (1%) resulted in greater damage. The USACE Aquatic Plant Information System recommends 0.75 to 1.0% concentration of Rodeo® with a nonionic surfactant. The maximum allowable concentration of Rodeo® is 1.5%. Other glyphosate-based trade products include: Aquamaster®, EraserAQ®, Touchdown Pro®, and AquaNeat®.

SonarQ® (5% fluridone in a pelleted form, SePRO Corp. Carmel, IN) is an aquatic herbicide that does not control the growth of *P. hemitomon*, but it does partially control *P. repens*. Arsenal® (BASF, Research Triangle Park) controls *P. hemitomon* in pasture conditions, but this form of 2,4D is not allowed in aquatic environments. Other formulations of 2,4D suitable for aquatic application will control *Typha* spp. and *Schoenoplectus* spp. but not *P. hemitomon* (U.S. Army Corps of Engineers, Aqautic Plant Information Service). An evaluation of three acetolactate synthase (ALS) herbicides on emergent wetland plants showed that *P. hemitomon* was generally the most tolerant to the three herbicides compared to the other species (in order of decreasing tolerance: *P. hemitomon>Paspalidium geminatum>Schoenoplectus validus>Sagittaria lancifolia>Pontederia cordata*; Koschnick et al. 2007).

SUMMARY

The persistence of *P. hemitomon* in southeastern freshwater wetlands can be explained by its competitive ability during stressful extremes such as drought, flooding, and fire. It has vigorous vegetative clonal growth and attains a moderate height and relatively high biomass production. Once established, it out-competes most annuals and coexists with other perennial species. However, for maidencane to remain dominant on drier sites, burning may be required to prevent displacement by woody species. Under wet conditions, it contributes to rapid peat accumulation (0.75 to 1.02 cm yr^{-1}; DeLaune et al. 1986, Nyman et al. 2006). Attempts to control the abundance of maidencane by flooding alone will not be successful unless culms are removed (i.e., fire, grazing, or mowing) followed with deep flooding. Herbicides are the most popular control method.

For wetland restoration, maidencane is a good candidate for ameliorating sites that have been contaminated with crude oil, but not if brine is also present. It grows well on coal and phosphate mining spoil deposits, and it has been successfully used to remove nutrients from several types of wastewater. Given its prolific root growth and rapid spread, it has proven useful in protecting shorelines and levees from erosion. Maidencane multiplies quickly, which makes it easy to propagate under nursery conditions. On sites where herbivory is intense, field establishment may be difficult. Unique methods have not been developed for large-scale establishment in soils that have poor load-bearing capacity. For wetland restoration projects requiring rapid colonization, perennial persistence, tolerance of multiple environmental gradients, and control of some exotic plant species, maidencane should be considered a candidate among high performance species.

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