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Characteristics of Sediments Associated with Submersed Plant Communities in the Lower Mobile River Delta, Alabama

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ABSTRACT

Sediments are an important factor influencing growth of submersed aquatic vegetation (SAV). We collected sediment cores from communities of Eurasian watermilfoil (*Myriophyllum spicatum* L.), native SAV, and sparsely vegetated SAV in the lower Mobile River Delta and examined relationships between general sediment characteristics (texture, pH, carbon, nitrogen, and phosphorus) and distribution and abundance of species of SAV. We found that sediments were similar between native and sparsely vegetated plant communities. Sediments from milfoil communities had less sand (9%) and more clay (57%) than sparsely vegetated communities. Sediments from milfoil communities also had higher concentrations of carbon and nitrogen in 0-5 cm and 5-10 cm sections of cores than native SAV and sparsely vegetated communities. Low current velocity and high sedimentation rates in milfoil communities likely contributed to high concentrations of carbon, nitrogen, and clay at these sites.

Key words: Eurasian watermilfoil, *Myriophyllum spicatum* L., restoration, submersed aquatic vegetation.

INTRODUCTION

Eurasian watermilfoil (*Myriophyllum spicatum*; hereafter milfoil) is an exotic species of submersed aquatic vegetation (SAV) that forms a dense canopy, grows rapidly, and has multiple mechanisms of propagation, enabling it to dominate submersed plant communities (Couch and Nelson 1985, Nichols and Shaw 1986, Lillie 1990, Smith and Barko 1990, Madsen and Smith 1997). Establishment of milfoil often leads to declines in abundance and diversity of desirable native species of SAV, such as tapegrass (*Vallisneria americana*), and reduced abundance of native SAV can negatively affect fish and wildlife (Aiken et al. 1979, Godfrey and Wooten 1981, Madsen et al. 1991, Duffy and Baltz 1998, Knapton and Petrie 1999, Getsinger et al. 2002). Milfoil also alters nutrient cycles (Seki et al. 1979, Getsinger et al. 2002, Madsen et al. 1991) and decreases water flow (Aiken et al. 1979), which can result in further habitat degradation.

Milfoil is a superior competitor to native SAV species under a wide range of environmental conditions; however, certain conditions may provide native plants advantages over milfoil (Titus and Adams 1979, Carpenter 1980, Madsen et al. 1991, Harley and Findlay 1994, Madsen and Smith 1997). Many native species of SAV, such as tapegrass and *Potamogeton* spp., for example, reach maximum photosynthetic rates at lower light levels than milfoil, which could give these plants competitive advantages in conditions where light availability is low (Madsen et al. 1991, Harley and Findlay 1994). Native species of SAV also are more tolerant of wave action than milfoil (Stewart et al. 1997, Ailstock et al. 2000). Consequently, spatial and temporal distribution of milfoil and native SAV species may vary according to environmental conditions (Titus and Adams 1979, Van et al. 1999).

Water parameters, such as turbidity, salinity, and dissolved nutrients, frequently are the primary factors influencing growth of SAV in estuarine environments (Carter and Rybicki 1990, Montague and Ley 1993, Carr et al. 1997). However, sediment properties, such as texture and nutrient availability, also are important to SAV growth (Brunner and Batterson 1984, Barko and Smart 1986, McFarland and Barko 1987, Short 1987, Nichols 1994, Spencer 1990). Species of SAV respond differently to sediment conditions, which can influence their distribution and abundance (Barko and Smart 1980, 1983, 1986). Van et al. (1999), for example, demonstrated that competitive abilities of tapegrass and hydrilla (*Hydrilla verticillata*) were influenced by sediment fertility. Tapegrass was dominant on sediments with low fertility, whereas hydrilla was dominant on sediments with high fertility (Van et al. 1999).

In this study, we determined general sediment characteristics in milfoil, native SAV, and sparsely vegetated communities in the lower Mobile Delta, Alabama. Our goal was to examine relationships between sediments and growth of SAV species. We predicted that milfoil would be more abundant than native species of SAV on sites with high fertility.

MATERIALS AND METHODS

The Mobile River System is the sixth largest river system in the United States, receiving water from four states and having a watershed area of 111,369 km^2 (Lamb 1979). The confluence of the Tombigbee and Alabama rivers in south Alabama marks the beginning of the Mobile River and Mobile River Delta. The Mobile River Delta is about 64 km long by 16 km wide and encompasses >81,000 ha (Beshears 1979).

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The lower Mobile Delta is about 25% (20,235 ha) of the total area of the Mobile River Delta and is generally described as the treeless area from Chuckfey Bay south to 4.0 km below US Highway 90 (Beshears 1979; Figure 1). Large shallow bays with an abundance of SAV and emergent marsh characterize the lower Delta (Beshears 1979). Fifteen species of SAV are present in the lower Mobile River Delta, including the exotics hydrilla and milfoil (Zolczynski and Shearer 1997). Native species of SAV abundant in the Delta include tapegrass, coontail (*Ceratophyllum demersum*), water stargrass (*Heteranthera dubia*), southern naiad (*Najas guadalupensis*), small pondweed (*Potamogeton pusillus*), and widgeon grass (*Ruppia maritime*; Zolczynski and Shearer 1997).

Hydrilla was first identified in Mobile Delta in 1990 (Zolczynski and Shearer 1997). Milfoil was first observed in Mobile Delta in 1975 and has been associated with significant declines in native submersed plant abundance (Zolczynski and Eubanks 1990). In 1979, milfoil was the dominant submersed plant in the lower Mobile Delta and was estimated to cover at least 85% of shallow growing areas (Zolczynski and Eubanks 1990). Distribution and abundance of milfoil and native SAV vary annually; however, submersed plant surveys in 1987 and 1994 identified milfoil as the dominant submersed plant (Zolczynski and Shearer 1997). Plant surveys conducted in 2002 indicate that milfoil remains an abundant submersed species in the lower Delta (Mapping of SAV in Mobile Bay and Delta 2004).

In June 2003, sampling sites ($n = 20$) were established in three bays (Big Bateau, Chacaloochee Bay, and Justin's Bay) in the lower Mobile Delta (Figure 1). Sites were established in SAV communities visually identified as milfoil, native SAV, and sparsely vegetated. We used subplots (0.25 m^2; $n = 5$) to estimate plant biomass and species composition of SAV at sites in September 2003 and 2004. Subplots were placed at the center of each site and 10 m from this point in each cardinal direction. All above-ground plant parts were collected by hand, and plant materials were placed in plastic bags, stored on ice, and transported to the laboratory at Auburn University. Samples were rinsed, sorted by species and dried (60 C) to constant mass (0.1 g).

We collected sediment cores ($n = 5$) at sites in March 2004 using plastic tubes (5 by 20 cm). Sediment cores were taken at the center of each site and 10 m from this point in each cardinal direction. Each core was separated into three sections (0-5 cm, 5-10 cm, and 10-20 cm) and sections were placed in plastic bags, stored on ice, and transported to the laboratory at Auburn University.

Plant material was removed from 0-5 cm sections and all sections were dried (65 C) to constant mass (g). Dried cores were ground to pass a 2-mm stainless steel sieve, and a composite sample from each depth section at each site was used to determine substrate texture, pH, extractable phosphorus (mg/kg), total carbon (g/kg), and total nitrogen (g/kg). Texture was determined by the hydrometer method (Sediment survey investigations staff 1991). Substrate pH was determined on 1:1 sediment/water slurries with a pH meter and glass electrode. Extractable P was determined by extracting samples with a dilute double acid solution (Hue and Evans 1986), followed by inductively coupled argon plasma spectroscopy (SPECTRO CIROS, Germany). Total carbon (C) and nitrogen (N) were determined with a LECO CN-2000 analyzer (LECO Corp., St. Joseph, MI).

Each year we determined total dry mass and dry masses of milfoil and native species of SAV at each sampling site. Native species of SAV included all species except milfoil and hydrilla. Three-way ANOVA (PROC GLM; SAS Institute 2003) was used to test effects of site, plant community (milfoil, native SAV, or sparsely vegetated), core depth (0-5 cm, 5-10 cm, and 10-20 cm), and their interactions on sediment parameters. Site was specified as a random variable, and plant community (site) was the error term used to test for plant community effects. Differences between least squares means were determined using Tukey-Kramer test. Tests were considered to be significantly different at $P \leq 0.05$.

RESULTS

Seven species of SAV were encountered at sampling sites (Table 1). Milfoil was most abundant at milfoil sites, and tapegrass and water stargrass dominated native SAV sites. Milfoil, tapegrass, and Southern naiad were most abundant at sparsely vegetated sites. However, total dry mass of SAV at sparsely vegetated sites was much lower (>75%) than at either milfoil or native SAV sites.

Texture. Overall mean percent sand varied from 72 ± 8.8% at sparsely vegetated sites to 40 ± 8.8% at milfoil sites, but differences were not significant among plant communities ($F_{2,17} = 3.37$, $P = 0.058$). However, percent sand was greater at 0-5 cm than at 10-20 cm in all plant communities ($F_{2,34} = 4.87$, $P = 0.014$; Figure 2A). Overall mean percent silt varied from 17 ± 5.4% at sparsely vegetated sites to 33 ± 5.4% at milfoil sites, but differences were not significant among plant communities ($F_{2,17} = 2.43$, $P = 0.118$) or core depths ($F_{2,34} = 0.57$, $P = 0.572$). Overall mean percent clay was greater at milfoil sites than at sparsely vegetated sites ($F_{2,17} = 4.28$, $P = 0.031$; Figure 3) and was greater at 10-20 cm than at 0-5 cm across all plant communities ($F_{2,34} = 9.18$, $P = 0.001$; Figure 2B).

pH. pH was similar across plant communities ($F_{2,17} = 1.22$, $P = 0.319$) and core depths ($F_{2,34} = 0.37$, $P = 0.693$) and averaged 5.43 ± 0.09.

Carbon, nitrogen, and phosphorus. Total C ($F_{4,34} = 4.88$, $P = 0.003$) and total N ($F_{4,34} = 4.34$, $P = 0.006$) varied with the interaction of plant community and core depth. Total C and N were higher at milfoil sites than at either native SAV or sparsely vegetated sites at depths of 0-5 cm and 5-10 cm, but not at 10-20 cm (Table 2, Figure 4A, B). Total C and N did not differ ($P > 0.05$) between native SAV and sparsely vegetated sites at any core depth (Table 2, Figure 4A, B). Extractable phosphorus also varied with the interaction of plant community and core depth ($F_{4,34} = 4.30$, $P = 0.006$). Phosphorus levels were greater at sparsely vegetated sites at 10-20 cm than milfoil sites at 10-20 cm and native SAV sites at 5-10 cm (Table 2, Figure 4C).

DISCUSSION

Texture, pH, and carbon and nitrogen concentrations of sediments were similar at sparsely vegetated and native SAV sites. Only phosphorus concentrations were different between these sites, and phosphorus was more abundant at sparsely

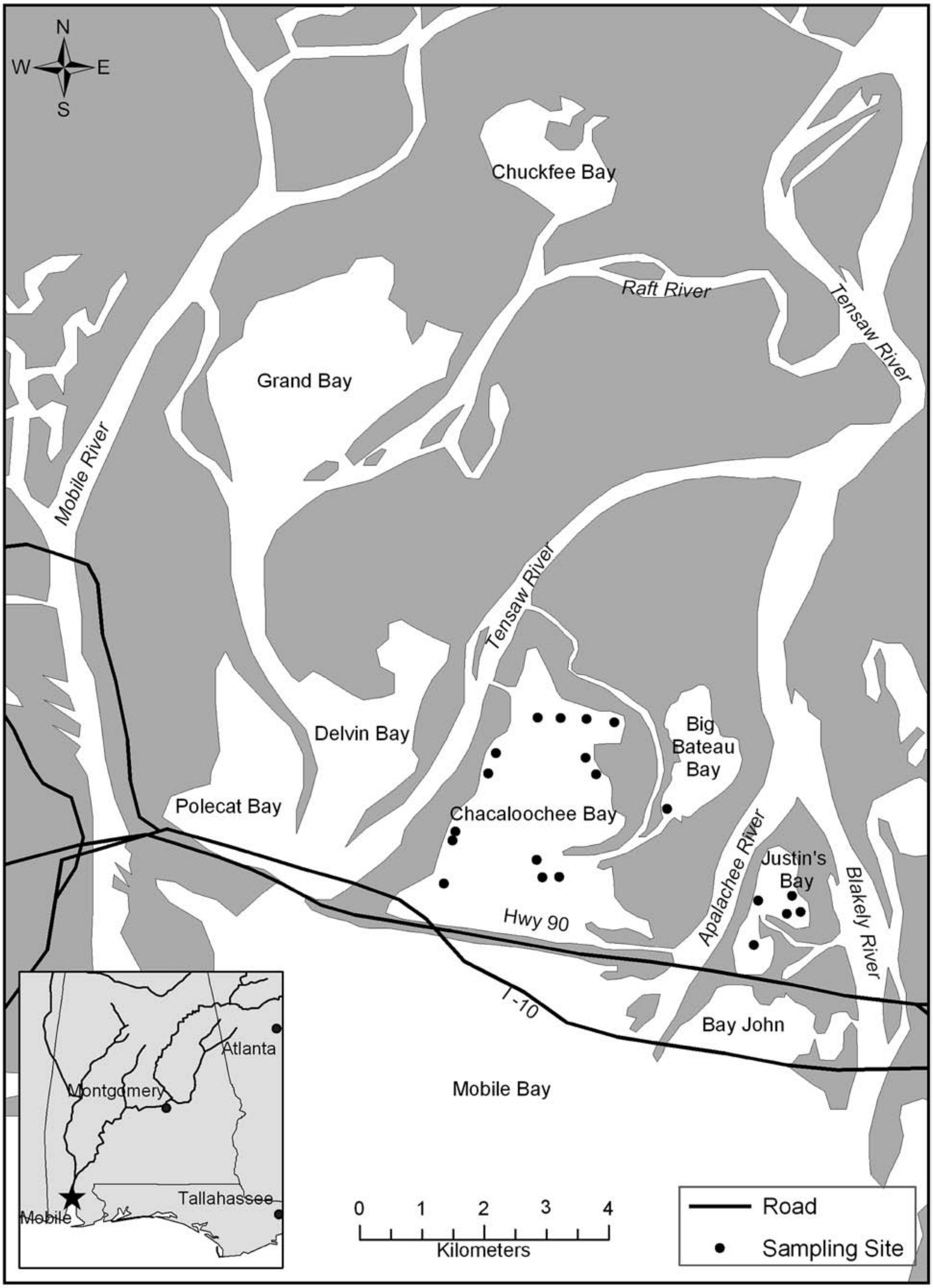

Figure 1. Map of lower Mobile River Delta, Alabama, showing locations of sampling sites.

Table 1. Dry mass ($\bar{x}$ ± SE) of submersed aquatic vegetation (SAV) at sampling sites ($N = 20$) in the lower Mobile River Delta, Alabama, September 2003 and 2004.

			Dry mass (g/m^2)	
Plant community[a]	n[b]	Species	$\bar{x}$	SE
Milfoil	7	Milfoil	111.2	22.4
		Southern naiad	9.2	3.2
		Coontail	8.8	5.2
		Tapegrass	3.2	3.2
		Small pondweed	0.4	0.4
		Water stargrass	0.4	0.4
Native species	6	Tapegrass	85.6	35.2
		Water stargrass	34.8	20.8
		Coontail	16.4	16.0
		Milfoil	14.8	10.4
		Southern naiad	5.6	2.8
		Hydrilla	Tr[c]	
		Small pondweed	Tr	
Sparsely vegetated	7	Milfoil	14.0	4.8
		Southern naiad	6.4	3.2
		Tapegrass	4.4	4.4
		Widgeon grass	2.0	2.0
		Small pondweed	0.4	0.4

[a] Sampling sites placed into plant communities according to mean dry mass of SAV collected in subplots September 2003 and 2004. Milfoil = mean dry mass of milfoil ≥60% of mean total dry mass, Native SAV = mean dry mass of native species of SAV ≥60% of mean total dry mass, and Sparsely vegetated = mean total dry mass of SAV <60 g/m^2.

[b] Sampling sites.

[c] Trace amounts (<0.4 g/m^2).

vegetated sites than at native SAV sites. Similarities between sediments at sparsely vegetated and native SAV sites suggest that the examined sediment characteristics did not limit growth of native SAV at sparsely vegetated sites. Sediments play a secondary role to other habitat conditions, such as light availability, in limiting growth of SAV in many estuarine environments, and other environmental factors were likely responsible for the lack of SAV growth at sparsely vegetated sites (Dennison 1987, Stevenson et al. 1993, Ailstock et al. 2000).

After plant communities become established, sediments in SAV communities are influenced by complex feedback mechanisms between growth of SAV and the surrounding environment (Almasi et al. 1987, Ailstock et al. 2000). Reduced current velocity and wave energy in SAV beds often result in high concentrations of fine particles, organic matter, and nitrogen (Scoffin 1970, Grady 1981, Wanless 1981, Kenworthy et al. 1982, Fonseca and Cahalan 1992, Rybicki et al. 1997). The effects of SAV on the surrounding sediment in turn influence growth of SAV (Ailstock et al. 2000).

Aquatic macrophytes influence sediments differently (Moore et al. 1994, Wigand et al. 1997). Sediments colonized by tapegrass, for example, retain more inorganic phosphorus than those occupied by milfoil and hydrilla (Wigand et al. 1997). Submerged aquatic vegetation communities comprised of exotic canopy-forming SAV species have lower current velocity and less wave action than those dominated by meadow-forming native species of SAV, which leads to high

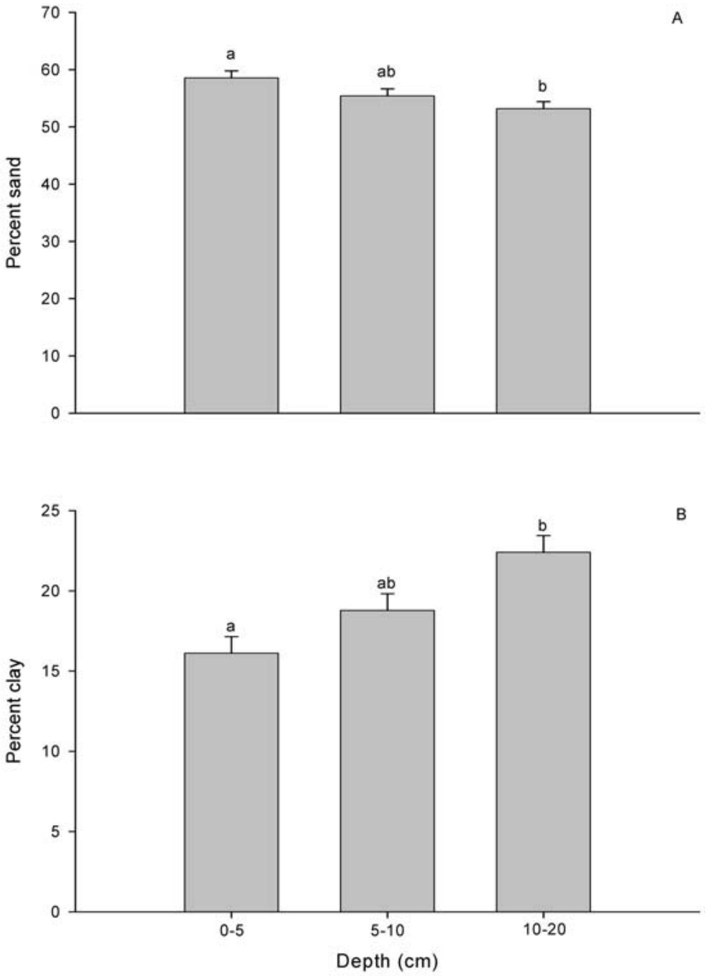

Figure 2. Mean (± SE) percents sand (A) and clay (B) in sections of sediment cores collected in submersed aquatic vegetation (SAV) communities in lower Mobile Delta, Alabama, March 2004. Means sharing same letter are not different at $P = 0.05$.

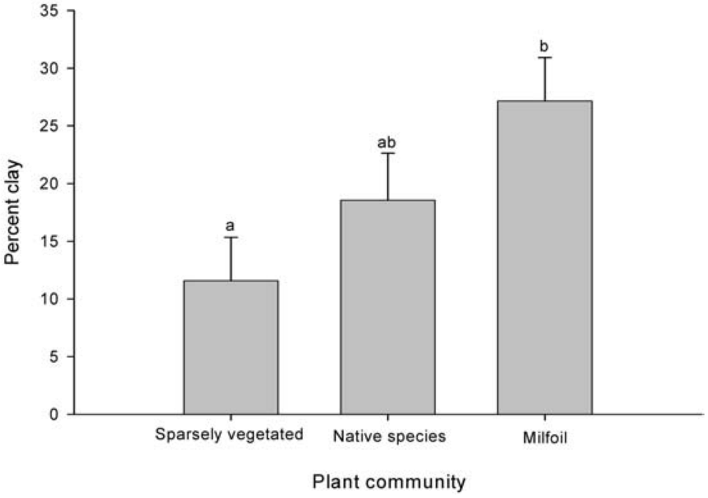

Figure 3. Mean (± SE) percent clay in sediment cores collected in submersed aquatic vegetation (SAV) communities in lower Mobile Delta, Alabama, March 2004. Means sharing same letter are not different at $P = 0.05$.

Table 2. Least squares means (± SE) of sediment parameters measured at sampling sites in submersed aquatic vegetation (SAV) communities in the lower Mobile Delta, Alabama, March 2004.

		SAV Community		
Parameter	Core depth (cm)	Milfoil	Native SAV	Sparsely vegetated
Total carbon (g/kg)	0-5	36.7 ± 2.2	16.9 ± 2.3	10.1 ± 2.2
	5-10	30.5 ± 2.2	17.4 ± 2.3	13.2 ± 2.2
	10-20	20.5 ± 2.2	16.3 ± 2.3	11.5 ± 2.2
Total nitrogen (g/kg)	0-5	4.3 ± 0.3	1.9 ± 0.3	1.0 ± 0.3
	5-10	3.3 ± 0.3	1.7 ± 0.3	1.1 ± 0.3
	10-20	2.1 ± 0.3	1.4 ± 0.3	0.9 ± 0.3
Extractable phosphorus (mg/kg)	0-5	12.4 ± 0.8	12.6 ± 0.9	12.3 ± 0.8
	5-10	11.9 ± 0.8	10.7 ± 0.9	13.1 ± 0.8
	10-20	9.2 ± 0.8	12.8 ± 0.9	15.1 ± 0.8

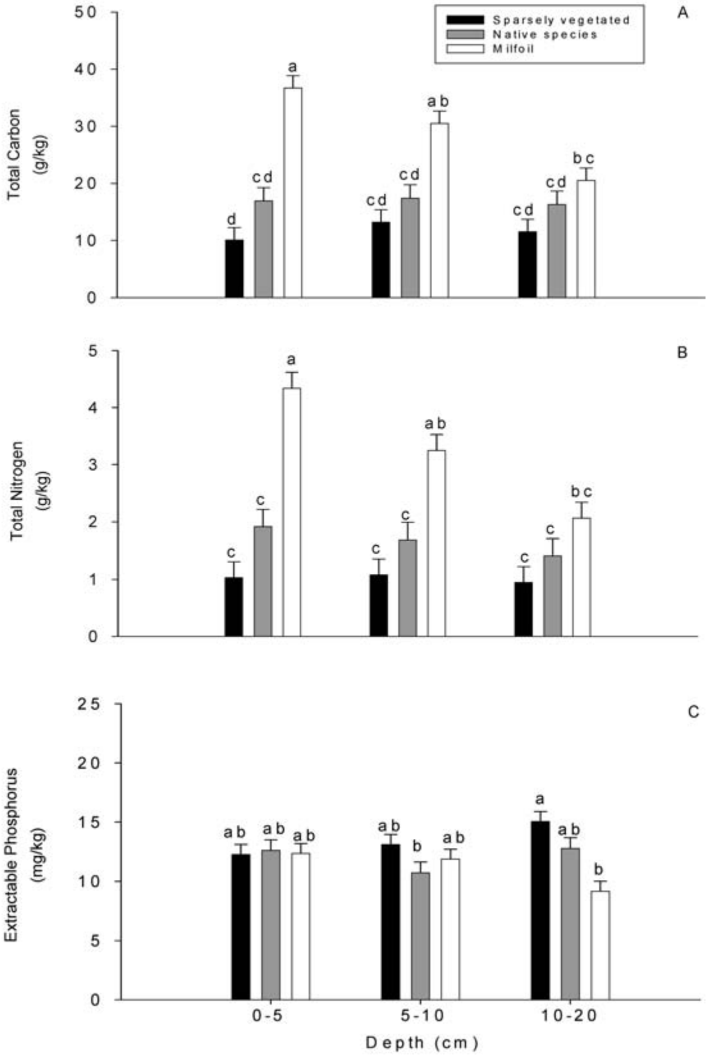

Figure 4. Mean (± SE) total carbon (A), total nitrogen (B), and extractable phosphorus (C) in sections of sediment cores collected in submersed aquatic vegetation (SAV) communities in lower Mobile Delta, Alabama, March 2004. Means sharing same letter are not different at *P* = 0.05.

rates of sedimentation and an abundance of fine particles in exotic SAV communities (Ailstock et al. 2000). Sediments with large amounts of clay have low porewater exchange with the water column, which can contribute to increased nitrogen concentrations (Kenworthy et al. 1982). Higher sedimentation rates at milfoil sites possibly contributed to greater abundance of clay and higher levels of nitrogen at these sites than sparsely vegetated sites. Milfoil also exhibits extensive leaf sloughing (Aiken et al. 1979), which, coupled with high rates of sedimentation, may have contributed to increased organic carbon and nitrogen concentrations at milfoil sites. Phosphorus concentrations were lower at both milfoil and native SAV sites than at sparsely vegetated sites, which may have been related to uptake of sediment phosphorus by SAV.

High levels of nitrogen, carbon, and clay in sediments associated with milfoil raise questions concerning long-term impacts of milfoil infestations. Studies have demonstrated that exotic canopy-forming SAV species tend to dominate nutrient-rich sediments, whereas less productive sediments often are occupied by native species of SAV (Hutchinson 1975, Van et al. 1999). Consequently, the accumulation of nitrogen in sediments associated with milfoil may provide exotic SAV species further competitive advantages over native SAV species.

Abundance of SAV is reported to decline as sediment organic content increases (Walker 1972, Wetzel 1979, Kight 1980, Barko and Smart 1983, 1986), possibly due to nutrient limitations on sediments with large amounts of fine particles (Barko and Smart 1986) or high concentrations of phytotoxic substances (e.g., sulfide) and soluble organic compounds (Barko and Smart 1983, Carlson et al. 1994). Barko and Smart (1986), for example, demonstrated that milfoil and hydrilla declined as sediment organic matter increased to 20% dry sediment mass. Concentrations of organic carbon in sediments at milfoil sites in the lower Mobile Delta were within the known ranges for most SAV species (typically below 50g/kg; Ward et al. 1984, Koch 1999, Ailstock et al. 2000); however, high rates of organic matter deposition and increased amounts of clay may contribute to declines in overall abundance of SAV. Milfoil often declines after dominating for a 5-10-year period, which may be partially related to the accumulation of organic matter in sediments (Carpenter 1980, Smith and Barko 1990). Unfavorable sediment conditions resulting from milfoil infestations may also impede native SAV restoration, despite declines in milfoil abundance. Further, succession of aquatic plant communities from submersed to emergent is related to the accumulation of organic matter in sediments (Wetzel 1979, Barko and Smart 1983), and milfoil may accelerate natural rates of succession in aquatic plant communities by increasing rates of organic matter deposition.

Sediments can be an important contributing factor causing variation in abundance and distribution of SAV. Sediment-plant relationships characterized in the lower Mobile Delta support results from other studies and suggest that milfoil is more abundant than native SAV in areas with high concentrations of carbon and nitrogen. Lower levels of phosphorus in sediments associated with milfoil and native SAV suggest that sediment phosphorus is important for growth of SAV. However, it is unlikely that sediment phosphorus limits growth of SAV because plants can also utilize inorganic nutrients from the water (Denny 1972, Barko and Smart 1983).

Although cause-and-effect relationships can not be determined from our results, the abundance of carbon, nitrogen, and clay in sediments associated with milfoil raises interesting questions about potential impacts of the plant on aquatic sediments. It is possible that growth of milfoil contributes to changes to aquatic sediments that have the potential to alter natural succession patterns in aquatic plant communities and impact restoration of native SAV. Removal of exotic SAV species such as milfoil soon after initial infestation may be important in reducing their impact on aquatic sediments and minimizing potential adverse ecologic impacts.

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