Relationships of submerged aquatic vegetation of Mississippi Coastal river systems

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Submerged aquatic vegetation (SAV) provide many valuable environmental functions. Unfortunately, their abundance has declined globally and their location within the watershed has shifted due to landscape alterations. The purpose of this study is to develop habitat indices that can be widely used to predict SAV type and their distribution in varying locations and habitat or basin types. SAV communities of shallow waters in channels, adjoining bayous, streams, inlets, and lagoons of the Pascagoula River, Back Bay of Biloxi, and Pearl River systems of coastal Mississippi were surveyed from May 2008 to June 2010. The survey extended upstream to where stream width became narrow and shade from tall trees on the shore restricted SAV growth. The location and species of SAV and the nearby floating aquatic and dominant shoreline emergent plants were recorded. The locations were added onto base GIS (Geographic Information System) maps for determination of landscape parameters. Locations were partitioned by presence or absence of each of four important SAV species for comparison of the following landscape features: distance to the Mississippi Sound, width of water course, and frequency of occurrence of other SAV and shore vegetation species. Analysis of SAV occurrence in the Mississippi coastal river systems indicates that a substantial number of plant associations exist. Plant-site associations were not fully explained by salinity tolerance alone, and may be influenced by multiple inherent traits of the individual species. The results aid the identification of potentially good sites for SAV restoration, as well as to predict how landscape alteration could affect their distribution and abundance.

Key words: Aquatic plants; Mississippi; Pearl River; Pascagoula River; Back Bay of Biloxi; SAV; Coastal Plant Communities.

Introduction

Aquatic plants are adapted to a variety of sites and exhibit different growth forms [1]. One of those growth form groups, submerged aquatic vegetation (SAV), provides numerous ecosystem services as food or cover for juvenile stages of finfish and shellfish, for small aquatic organisms, and for water birds; they also function in sediment stabilization, buffering wave energy, and nutrient uptake and sequestration [2]. These functions in turn support the food chain and the commercial and sport fishing industry.

Several freshwater and brackish species of SAV common to the Mississippi coast are preferred foods of waterfowl, marsh birds, and shore birds (waterbirds). *Ruppia maritima* L (Widgeongrass), *Najas guadalupensis* (Spreng.) Magnus (Southern naiad), *Potamogeton pusillus* L (Small Pondweed), and *Zannichellia palustris* L (Horned Pondweed) are all preferred over other species [3]. *Ruppia maritima* is one of most wide-spread coastal SAVs in the USA with excellent nutritional value for waterfowl [4]. *Vallisneria americana* Michx (Wildcelery) is known to be one of the most valuable duck foods in the northeastern US. It is grazed by many aquatic and wetland inhabitants [5,6].

Unfortunately, global coastal SAV abundance has been declining which is of great concern [7].

Distribution shifts of SAV communities within watercourses as well as recent regional extinctions have occurred following widespread application of certain land management practices throughout the watershed [8]. Fragmentation of SAV communities has also been found to be a result of direct impacts of anthropogenic activities within the habitat [9]. Clearly, knowledge of SAV occurrence is essential for assessments of ecological status and economic potential and for their proper conservation and management. To better understand occurrence, declines, and restoration potential, several models have been developed; however, they are based on long-term monitoring data [10]. Resource managers have limited ability to conduct extensive and consistent water quality monitoring, hence, usage of those models is limited to areas with good long-term datasets.

The need for efficient habitat indices that can be widely used to predict SAV type and distribution has been recognized. SAV has received limited attention in the brackish and intermediate coastal waters even though their functions in those waters are valuable [11,12]. The published information on brackish and freshwater plant species along the Mississippi mainland coast is lacking [13]. The objective of this study is to model coastal SAV communities in the fresh and brackish zone of Mississippi coastal river systems using relatively static features (geographic, topographic, and shoreline vegetation parameters) that do not require long-term monitoring data.

Experimental Section

Study Area

Our study area was shallow water courses (Figure 1) along three major river systems which empty into the estuaries of coastal Mississippi: Pascagoula River, Back Bay of Biloxi, and Pearl River. The drainages of the Pearl and Pascagoula Rivers reach into the North and Central portions of the state, while the Biloxi Bay System drains only the lower and coastal regions.

Methods

SAV communities of shallow waters in channels, adjoining bayous, streams, inlets, and lagoons of the three major river systems of coastal Mississippi were surveyed from May 2008 to June 2010 (Figure 2). The location and species of SAV and nearby floating aquatic and shoreline emergent plants were recorded. The survey extended from the river mouth to approximately 32 km upstream. Survey methods included raking from a boat and wading in the water, after SAV were observed to occur in a given location. In addition to species and bed location, GPS coordinates of the shores that bear the bed were recorded using a Trimble™ GeoXH handheld GPS unit and TerraSync™ software.

The survey locations were added onto base GIS (Geographic Information System) shoreline maps as point data. Distance to the Mississippi Sound and width of the water course at each location was determined. The SAV occupied sites were partitioned by presence or absence of each of four species for comparison of the following landscape features: distance to the Mississippi Sound, width of water course, and frequency of occurrence of other SAV and shore vegetation species. *Ruppia maritima* was selected because of its high salinity tolerance and outstanding value for waterbirds. *Zannichellia palustris* represents moderately high salinity tolerance and was the second most frequently occurring SAV. *Vallisneria americana* has moderate salinity tolerance, was the most frequently occurring SAV, and has outstanding value for waterbirds. *Potamogeton pusillus* was selected because of its low tolerance for salt and because this genus is unsurpassed among SAV for its value to waterbirds.

Results

Only sites that had SAV communities within the fresh and brackish zones of the Pascagoula River (n=30), Biloxi Back Bay (n=18), and Pearl River (n=23) systems were surveyed for a total of 71 survey locations. *Vallisneria americana* (39 locations), *Zannichellia palustris* (26 locations), *Najas guadalupensis* (22 locations), *Potamogeton pusillus* (14 locations), *Ruppia maritima* (9 locations), and *Ceratophyllum demersum* L (Coontail; 7 locations) were found to be dominant SAV at our study locations. These species appeared to be the most dominant SAV along the Mississippi coast [14]. Submerged macrophytic algae, *Nitella* sp. (Brittlewort) and *Chara* sp. (Muskgrass), occurred in several beds. Although these wetland plants are each unique in there ecological niche, they often have similar habitat requirements (Table 1).

Ruppia maritima

The most salt-tolerant SAV, *Ruppia maritima* (Table 1), occurred more frequently at sites closer to the Mississippi Sound (Table 2) where seawater encroachment is more prevalent than it would be in the locations farther upstream. It co-occurred with *Vallisneria americana* on 56% of the sites. *Potamogeton pusillus* and *Najas guadalupensis* occurred with *R. maritima*, but appeared to occur more frequently in the upper regions of the rivers where salinities remain fresh. *Ceratophyllum demersum*, and the two algae species that resemble SAV, *Chara* sp. and *Nitella* sp., did not co-occur with *R. maritima* at any site, presumably due to salt intolerance of those two algae species.

We found that *Ruppia maritima* occurred frequently (86% of the time) along the shores dominated by either *Spartina alterniflora* Loisel (Smooth Cordgrass) or *Spartina cynosuroides* (L.) Roth (Big Cordgrass). In the saltwater marshes, *R. maritima* was the primary component of SAV habitat of Biloxi Bay and the lower regions of Pearl River where it likewise often occurred along shores dominated by *S. alterniflora* and the dominant salt marsh plant in the Mississippi coast, *Juncus roemerianus* [14]. The emergent marsh plants, *Spartina patens*, *Schoenoplectus robustus*, and *Schoenoplectus tabernaemontani* also frequently occurred at sites with *R. maritima*. *Juncus effusus* and *Zizania aquatica*, which occur strictly in fresher areas, were not found at any *R. maritima* sites.

Vallisneria americana

The less salt-tolerant *Vallisneria americana* (Table 1) occurred more frequently at sites farther from the Mississippi Sound than did *Ruppia maritima* (Table 2). In these sites, frequency of *R. maritima* occurrence was similar regardless of the presence of *V. americana*. *Najas guadalupensis* and *Zannichellia palustris* were each present on approximately one-third of sites that had *V. americana*. *Z. palustris* and *Potamogeton pusillus* were more frequent on sites without *V. americana* (0.44 and 0.28, respectively) than on sites where *V. americana* occurred (0.31 and 0.13, respectively). Those relationships of low co-occurrence could be in response to differences in salinity tolerance; *Z. palustris* being more salinity tolerant while *P. pusillus* exhibits a lower threshold than *V. americana*.

Vallisneria presence was not affected by the frequency of any of the shore vegetation species of Spartina or Schoenoplectus. *Juncus roemerianus* occurred at approximately three-fourths of the *V. americana* sites.

Zannichellia palustris

Also less salt-tolerant than *Ruppia maritima*, *Zannichellia palustris* (Table 1) occurred more frequently at sites farther from the Mississippi Sound than did *R. maritima* (Table 2). Frequency of *R. maritima* does not differ between sites with or without *Z. palustris*. *Vallisneria americana* was less frequent on the *Z. palustris* occupied sites. *Najas guadalupensis* was present on approximately one-third of sites regardless of whether *Z. palustris* was present (38%) or absent (27%). *Potamogeton pusillus*, *Ceratophyllum demersum*, *Chara* sp., and *Nitella* sp. occurred with higher frequency on *Z. palustris* sites, which would not be expected based on salinity tolerance alone.

Juncus roemerianus co-occurred on approximately three-fourths of the *Zannichellia palustris* sites. *Schoenoplectus robustus* and *Spartina patens* appeared to grow more frequently with *Z. palustris* while *Zizania aquatica* appeared to be less frequent on those sites. Those occurrence relationships were presumably due to salt tolerance differences of those species as identified in Table 1.

Potamogeton pusillus

The least salt-tolerant species, *Potamogeton pusillus* (Table 1), occurred more frequently at sites farther from the Mississippi Sound (Table 2). Its low co-occurrence with *Ruppia maritima* and high co-occurrence with *Ceratophyllum demersum*, *Myriophyllum aquaticum*, *Chara* sp., and *Nitella* sp. indicated that salinity may control site suitability. The low co-occurrence with *Vallisneria americana* as well as high co-occurrence with *Najas guadalupensis* and *Zannichellia palustris* indicated that factors other than depth preference and tolerances for salinity and for disturbance (by current and waves) may have roles in site suitability for *P. pusillus*. *N. guadalupensis* was more likely to occur on sites with *P. pusillus* (0.64) than on sites without it (0.23). *Juncus roemerianus* was present at approximately half of the sites that had *P. pusillus*.

Discussion

The present analysis on frequency of SAV occurrence in the Mississippi coastal river systems indicates that a substantial number of plant associations exist. These associations will be helpful in predicting SAV occurrence and distribution as well as in identifying suitable sites for restoration and enhancement of those community types. Although *Ruppia maritima* co-occurred with *Zannichellia palustris* and/or with *Vallisneria americana*, there were sites that strictly had only *R. maritima* due to the regular influences by tidal salt water from the sound. This may be expected as *R. maritima* has the widest range of salt tolerance of all SAV species reported in this paper.

Salinity of the water body, well known as a major factor in determining SAV community type, would be expected to manifest its effect in a gradient in relation to distance from the sea. The extent of seawater encroachment up the streams and rivers may explain much of the loss in SAV communities of the northern Gulf of Mexico as was apparent for *Zannichellia palustris* and *Ruppia maritima* community shifts in the upper Chesapeake Bay [8].

The plant-site associations at our study sites are not fully explained by salinity tolerance alone. SAV community composition is reportedly affected by multiple inherent traits of the individual species (Table 1). For example, morphological adaptations and tolerances of each of the SAV species to wave energy, current, water depth, as well as other potential factors, could be important variables in that species' ability to colonize a site. Therefore, certain SAV communities would be expected to flourish within specific ranges in values for those variables. Those values may in turn correlate to certain landscape properties and states (i.e., shoreline aspect and slope, amount and type of forest coverage, urban coverage, soil types, channel profile, etc.). Detailed studies of the watersheds could conceivably reveal associations between the landscape properties and states and the SAV communities within those watersheds. Application of statistics to the most applicable variables from the group presented here and additional ones resulting from the study of landscape properties will aid in selection of the most valuable variables for a decision-tree model. Subsequently, a Habitat Suitability Index (HSI) for SAV could be developed via a decision-tree algorithm approach that utilizes these landscape properties. The tree-based algorithm for the index could be validated by assessing a separate set of field data. Application of the index would not be restricted to well-protected and monitored areas because the index will use geographic, topographic, and shoreline vegetation parameters. We anticipate that the resultant HSI would be effective in visualizing potential SAV bed locations and to predict how coastal landscape alteration would affect their distribution and abundance.

Conclusion

Submerged aquatic vegetation (SAV) communities of shallow waters in channels, adjoining bayous, streams, inlets, and lagoons of the Pascagoula River, Back Bay of Biloxi, and Pearl River systems of coastal Mississippi were surveyed and analyzed for their presence or absence with landscape features including distance to the Mississippi Sound, width of water course, and frequency of occurrence of other SAV and shoreline vegetation species. Our results indicated that plant-site associations are influenced by multiple inherent traits of the individual species and landscape features as the associations were not fully explained by salinity tolerance alone. The results aid the identification of potentially good sites for SAV restoration, as well as to predict how landscape alteration could affect their distribution and abundance.

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Table 1. Selected site requirements of dominant coastal Mississippi submerged aquatic vegetation.

	Habitat	Salinity (psu) [optimum]	Depth (m) [optimum]	Current & Waves	References
Ruppia maritima	fresh-saline; bayou, sheltered estuary, pond, bay, mud flat, stream	0-40; [14-30]	0.1-1.5 clay/silt; <4.5 over sand; [0.4-1.3]	low to moderate tolerance	4,8,15-23
Vallisneria americana	fresh-brackish stream, pond, lake, sound, marsh	<11 survive; <3 thrive; [<1]	0.3-2.0; [0.3-1.5] adaptable	tolerant; adaptable	15,19,22, 24-29
Najas guadalupensis	fresh-brackish pond, lake, pool, waterway	<10 survive; <7 thrive; [<1]	<4; [0.5-3.0]	low tolerance	15,19,22,27, 30,31
Zannichellia palustris	fresh-brackish stream, pond, lake, estuary	6-14 at known locations [<6]	shallow	low tolerance	8,15,20-22,32
Potamogeton pusillus	fresh-brackish stream, pond, pool, marsh, oxbow	very low	shallow	tolerant; adapt-able	15,19,21,22
Ceratophyllum demersum	fresh stream, pond, lake, bayou, marsh, swamp, pools	very low	0.5-15.5	low tolerance	15,19,22,33, 34
Cabomba caroliniana	fresh stream, pond, marsh, lake, river	fresh	<10 [1-3]	low tolerance	15,22,33-35

Table 2. Apparent associations among SAV brackish and freshwater sites in Mississippi coastal rivers.

	Ruppia maritima		***Vallisneria americana***		***Zannichellia palustris***		***Potamogeton pusillus***	
Landscape features (km)	Present	Absent	Present	Absent	Present	Absent	Present	Absent
Mean distance to sound	7.4	15.0	14.2	13.9	16.1	12.7	14.5	13.9
Mean width of water	0.19	0.10	0.10	0.11	0.10	0.16	0.16	0.11
Occurrence (frequency)								
SAV								
Ceratophyllum demersum	0.00	0.11	0.05	0.16	0.12	0.09	0.21	0.07
Chara sp.	0.00	0.08	0.05	0.10	0.15	0.02	0.21	0.04
Myriophyllum aquaticum	0.00	0.03	0.03	0.03	0.00	0.04	0.07	0.02
Najas guadalupensis	0.11	0.34	0.33	0.28	0.38	0.27	0.64	0.23
Nitella sp.	0.00	0.15	0.15	0.10	0.19	0.09	0.21	0.11
Potamogeton pusillus	0.11	0.21	0.13	0.28	0.27	0.16		
Ruppia maritima			0.13	0.12	0.12	0.13	0.07	0.14
Vallisneria americana	0.56	0.55			0.46	0.60	0.36	0.60
Zannichellia palustris	0.33	0.37	0.31	0.44			0.50	0.33
Shoreline vegetation								
Juncus effusus	0.00	0.05	0.00	0.11	0.04	0.05	0.07	0.04
J. roemerianus	1.00	0.60	0.76	0.50	0.73	0.59	0.50	0.69
Schoenoplectus robustus	0.14	0.03	0.05	0.04	0.08	0.03	0.07	0.04
S. tabernaemontani	0.29	0.16	0.19	0.14	0.19	0.15	0.36	0.12
Spartina alterniflora	0.43	0.10	0.16	0.11	0.15	0.13	0.14	0.14
S. cynosuroides	0.43	0.17	0.19	0.21	0.19	0.21	0.21	0.20
S. patens	0.14	0.05	0.05	0.07	0.12	0.03	0.00	0.08
Zizania aquatica	0.00	0.12	0.00	0.25	0.04	0.15	0.14	0.10

Figure 1. A shallow water course with dense aquatic vegetation.

Figure 2. The survey team consisted of 5 to 6 members.