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NOTE

COMMON REED *PHRAGMITES AUSTRALIS* OCCURRENCE AND ADJACENT LAND USE ALONG ESTUARINE SHORELINE IN CHESAPEAKE BAY

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Abstract: We completed a shoreline survey of *Phragmites* occurrence and adjacent land use along more than 8,400 km of shoreline in the Maryland and Virginia portions of the Chesapeake Bay and its tidal tributaries. *Phragmites* occurred along 14.6% of Maryland estuarine shoreline in the mid-to-upper portion of Chesapeake Bay, but along only 2.0% of the surveyed Virginia shoreline in the mid-to-lower portion. The dramatic difference in occurrence was not related exclusively to high salinity restrictions on plant distribution in the lower portion of the bay since most of the survey was completed in mesohaline to oligohaline sections of the estuary. *Phragmites* occurrence was highest—up to 30% of all shoreline—in the upper northeastern section of the bay and was over-represented adjacent to cleared but undeveloped land. Although *Phragmites* was found growing adjacent to all types of land uses including undisturbed forest in the mid-to-upper estuary, its occurrence was positively correlated with the percentage of agricultural shoreline. The extensive *Phragmites* occurrence throughout the upper estuary suggests that both local and regional environmental factors of management concern may contribute to the suspected spread of *Phragmites* along both Maryland and Virginia shoreline.

Key Words: agriculture, development, GIS, plant distribution

INTRODUCTION

Occurrence of common reed *Phragmites australis* (Cav.) Trin. ex Steud. in wetland environments of North America is notable both for the rapid expansion of a non-native form over the last century (Chambers et al. 1999, Saltonstall 2002, Meyerson et al. in press) and for the continued but suspected diminished presence of native haplotypes (Saltonstall 2003a, Saltonstall 2003b, Saltonstall et al. 2004, Vasquez et al. 2005, League et al. 2006, Packett and Chambers 2007). Expansion of the non-native form has been linked to localized wetland disturbance (Bart and Hartman 2002, Havens et al. 2003, Bart et al. 2006) and adjacent upland development and physical clearing of vegetation coupled with nutrient enrichment (Minchinton and Bertness 2003, Silliman and Bertness 2004). From a suspected epicenter of introduction in southern New England, probably during the mid-nineteenth century (Saltonstall 2002), non-native *Phragmites* has spread into tidal wetlands down the eastern U.S. seaboard and also into non-tidal wetlands across the U.S. (Meyerson et al. in press).

The Chesapeake Bay estuary, with a watershed population of seven million people and ongoing upland development, has provided ample opportunities for *Phragmites* invasion and expansion. Anecdotally, *Phragmites* is thought to be more extensive in the northern portion of the estuary, but this has never been demonstrated at the bay-wide scale. Because *Phragmites* is moderately salt-tolerant, much of the shoreline of Chesapeake Bay is susceptible to *Phragmites* invasion and spread. Further, recent analysis of land use in 30 Chesapeake Bay sub-watersheds indicated that local urban-suburban development was partially responsible for the relative abundance of *Phragmites* in coastal marshes (King et al. 2007). Our objective was to test whether the observed distribution of *Phragmites* along the Chesapeake Bay shoreline was correlated to land use in adjacent uplands of the estuary.

METHODS

For this project, we developed and completed an inventory to determine the occurrence of *Phragmites* along the estuarine shoreline of Chesapeake Bay. The shoreline inventory encompassed three major activities: field work for data collection, post-processing for differential GPS correction and subsequent conversion to digital GIS coverages, and creation of an electronic map inventory. The data inventory was based on a shoreline assessment approach that characterized conditions in the shore zone, defined for this study as the region extending from the upland edge of the riparian zone to the shoreline. The riparian zone generally represents the first 30 meters inland of the shoreline, which can be observed from the water. Four classes were established to comprise land use types along all shoreline: agriculture (croplands); forest (stands with height > 5.5 m and width > 9 m); open (cleared but undeveloped land including bare soils, grass, scrub-shrub, and clear-cut); developed (upland occupied by residential dwellings or commercial and industrial facilities).

Data collection was performed in the field starting in 2001 and ending in 2005. From a small, motorized vessel operating at slow speed parallel to the shoreline, surveys typically took place on a rising tide, allowing the boat with a one-meter draft to be as close to shore as possible. Nearness to shoreline depended on tide, bathymetry, and presence of obstructions. Data were logged using a handheld Trimble GeoExplorer 3 and the Geo XT GPS units. Both units are capable of decimeter accuracy, but the relatively short occupation of sites in the field reduced the accuracy to at-worst five meters. These accuracy limits were determined by ground truthing experiments and therefore reflect combined errors associated with global positioning and observations. Positioning errors are minimized by differential correction. Observation errors are minimized by using imagery to validate riparian land use and other detectable features. Since *Phragmites* cannot be discerned from available imagery, the maximum ± five meter positional errors apply to location of *Phragmites*. GPS units were programmed to collect information at a rate sufficient to compute a position anywhere along the course. Using a data dictionary, riparian land use and location of *Phragmites* were collected in a kinematic mode with one observation collected every five seconds. Kinematic GPS surveying is a technique for which positions are collected while in motion; the survey vessel moved along the survey track while data were collected. Static surveys, also known as fixed station surveys, were completed at a rate of one observation per second at shoreline structures including piers, boat ramps, and boathouses.

A base shoreline was developed from the most recent digital ortho photography (DOQQ) and all attributes were corrected and referenced to this base shoreline. The shoreline coverage was derived using photo-interpretation techniques combined with on-screen digitizing of the land-water interface observed on the DOQQs. Field data were processed using the Trimble Pathfinder Office and ESRI's ArcGIS software that spatially corrected the shoreline attributes to reflect their true position in the shore zone, rather than along the boat track. Upon completion of this step, all attributes were geographically referenced to the base shoreline generated from the DOQQs.

Estuarine shoreline of Chesapeake Bay for the entire state of Maryland (5,695 km) and a portion of Virginia (2,737 km) was inventoried for the occurrence of *Phragmites* (Figure 1). The inventory documented the presence of *Phragmites* along the shoreline but did not determine the total abundance or area coverage by *Phragmites*. Further, no attempt was made to differentiate between native and non-native forms of *Phragmites*. Packett and Chambers (2007), however, report that native and non-native forms are segregated along the Rappahannock River in Virginia, with native *Phragmites* found exclusively in tidal freshwater. Summaries of total length of shoreline occupied by *Phragmites* were completed by separate reaches throughout the bay, and also by state and adjacent riparian land use to determine regional patterns of occurrence and potential local influences on the spread of *Phragmites*. Finally, regression analysis compared the percent occurrence of *Phragmites* with the extent of different land use types along all surveyed shoreline, comprising 12 separate reaches in Maryland and Virginia.

RESULTS

From shoreline surveys (Figure 1), the occurrence of *Phragmites* in Maryland portions of the estuary was far more extensive than in Virginia. In Maryland where the entire estuarine shoreline was surveyed, *Phragmites* was noted along 830 km (14.6% of all shoreline), whereas in Virginia where the survey was less extensive, *Phragmites* occurred along 54 km (2.0% of shoreline). The highest percentage of *Phragmites* was found adjacent to agriculture in Maryland (23.2% of agricultural shoreline); in Virginia, the highest percentage of *Phragmites* was found adjacent to other open but undeveloped land (3.2% of open shoreline; Figure 2).

We calculated that agriculture occupied 10.9% of the total surveyed shoreline in Maryland. For

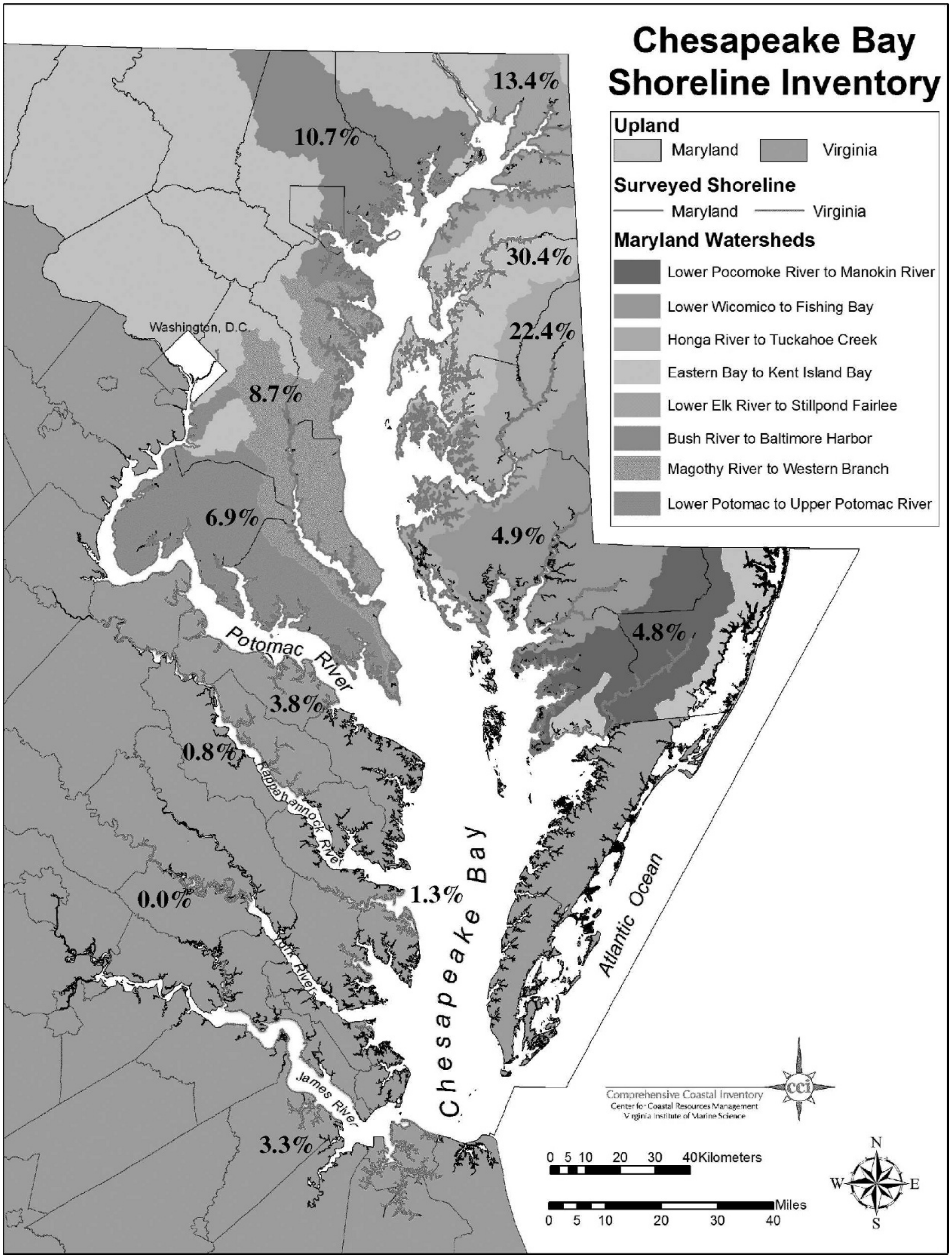


Figure 1. Maryland and Virginia portions of Chesapeake Bay included in the shoreline survey for occurrence of Phragmites and for adjacent land uses. In Maryland, the total shoreline is broken down into eight color-coded sub-watershed regions detailed in Table 1. For both Maryland and Virginia reaches surveyed, the total percentage of shoreline occupied by Phragmites is shown.

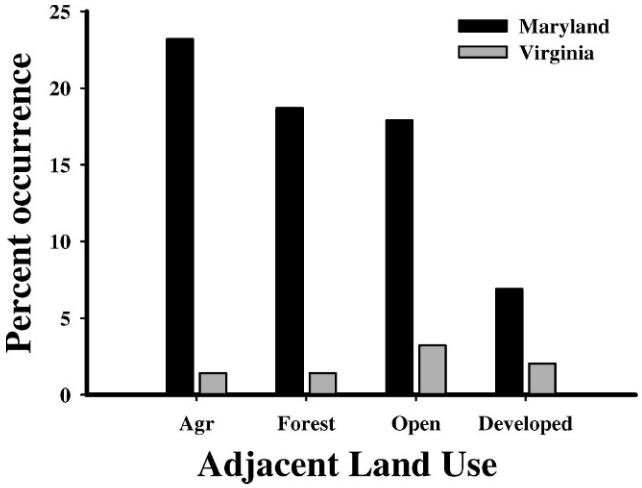
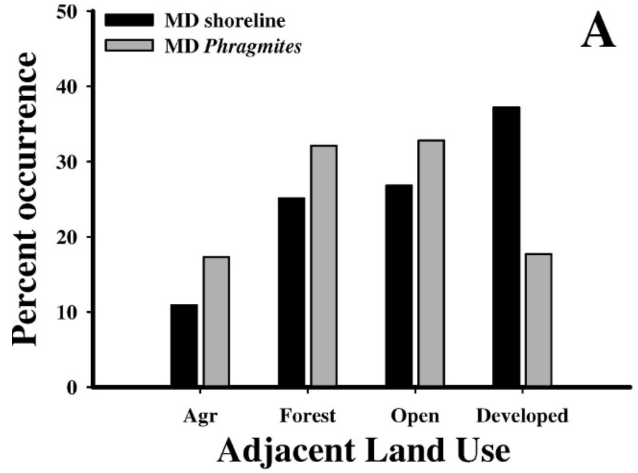


Figure 2. From boat surveys of adjacent land use, the percent of each shoreline type occupied by Phragmites for Virginia and Maryland portions of Chesapeake Bay.

comparison, 17.3% of all *Phragmites* shoreline occurred adjacent to crop agriculture. Thus, *Phragmites* was over-represented adjacent to agricultural shoreline in Maryland, but was also over-represented adjacent to forested and other open shoreline (Figure 3). The pattern of over-representation along open shoreline was observed in seven of eight reaches in Maryland and in all four reaches in Virginia where *Phragmites* occurred. In Virginia, crop agriculture occupied 5.3% of the surveyed shoreline and only 3.9% of all *Phragmites* occurred adjacent to agriculture. Similarly, *Phragmites* was under-represented adjacent to forest lands in Virginia.

Portions of the Maryland shoreline with the largest shoreline occurrence of *Phragmites* comprised the two northeastern bay reaches from Eastern Bay to Kent Island Bay (321 km, or 30.4%) and from Honga River to Tuckahoe Creek (207 km, or 22.4%) (Figure 1; Table 1). Reaches farther south in the Maryland portion of the estuary had a significantly lower percentage of shoreline occupied by *Phragmites* (goodness-of-fit $X^2_{(3,8)} = 19.8$, $p < 0.001$). For comparison, the largest shoreline occurrence in Virginia was found on the lower James River hydrologic unit, with only 28 km of *Phragmites* (3.3% of surveyed shoreline; Table 2). Among the 12 separate reaches in Maryland and Virginia, the percentage of *Phragmites* occurrence along the shoreline was positively correlated with the percentage of agriculture along the shoreline ($r^2 = 0.73$, $p < 0.01$), whereas no significant correlations were noted for *Phragmites* occurrence and forest ($r^2 = 0.02$, $p = 0.63$), open land ($r^2 = 0.10$, $p = 0.32$), or developed land ($r^2 = 0.19$, $p = 0.15$).



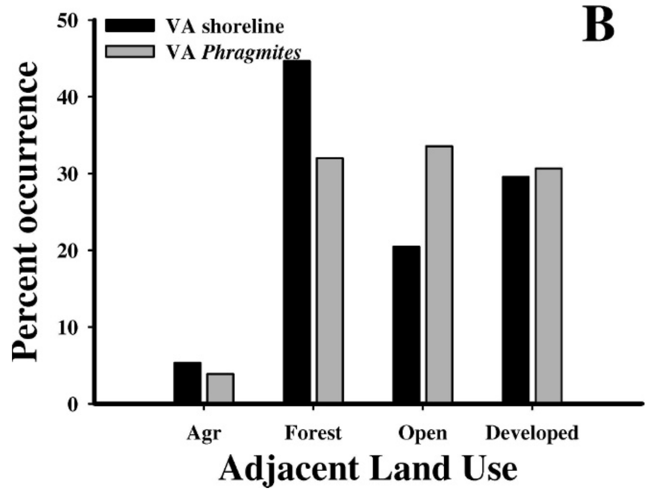


Figure 3. From boat surveys, relative extent of Phragmites by shoreline type, based on adjacent land use, for A) Maryland, and B) Virginia. For this figure, shoreline type percentages sum to 100% and Phragmites percentages sum to 100%, showing whether Phragmites is over- or under-represented with respect to the amount of each shoreline type present.

DISCUSSION

This work provides a large-scale summary of *Phragmites* occurrence in the Chesapeake Bay estuary. Despite the partial shoreline survey in the Virginia portion of Chesapeake Bay and absence of data on native and non-native distribution, some interesting patterns were revealed. First, a ''hot spot'' of *Phragmites* occurrence is apparent in the upper reaches of the estuary. We documented the greatest shoreline occurrence of *Phragmites*—up to 30%—from the northeastern region of Chesapeake Bay. The distribution of *Phragmites* generally was less extensive on the western shoreline of the bay and its tributaries, and much less extensive along

Table 1. Occurrence of *Phragmites australis* along the entire Maryland estuarine shoreline of Chesapeake Bay, summarized for eight separate reaches around the bay, starting at the Virginia border on the southern eastern shore (Lower Pocomoke River) and extending around the entire shoreline to the Virginia border on the southern western shore (Potomac River). Corresponding Maryland state hydrologic units are included. *Phragmites* occurrence is expressed as a percentage of shoreline with respect to four different categories of adjacent land use and to total shoreline (km total shoreline length for each category in parentheses).

Coastline	Hydrologic Units	% Agriculture	% Forest	% Open	% Developed	Total
Lower Pocomoke River to Manokin River	2130202–2130208	13.8 (13.7)	11.1 (96.6)	1.3 (368)	13.1 (65.5)	4.8 (545)
Lower Wicomico River to Fishing Bay	2130301–2130308	0.0 (12.7)	3.0 (73.4)	5.2 (262)	6.5 (61.8)	4.9 (410)
Honga River to Tuckahoe Creek	2130401–2130405	29.3 (218)	25.3 (193)	34.0 (152)	11.8 (360)	22.4 (924)
Eastern Bay to Kent Island Bay	2130501–2130511	29.9 (231)	41.3 (241)	42.1 (266)	12.8 (315)	30.4 (1053)
Lower Elk River to Stillpond-Fairlee	2130601–2130611	17.6 (33.9)	14.8 (135)	21.7 (87.7)	4.7 (123)	13.4 (379)
Bush River to Baltimore Harbor	2130701–2130903	0.0 (1.0)	24.6 (111)	21.0 (106)	2.7 (329)	10.7 (547)
Magothy River to Western Branch	2131001–2131103	3.5 (43.6)	14.3 (336)	14.6 (142)	4.9 (643)	8.7 (1164)
Lower Potomac River to Upper Potomac River	2140101–2140201	2.7 (67.9)	4.1 (241)	20.3 (141)	2.7 (223)	6.9 (673)

Virginia shoreline relative to Maryland. This pattern is not driven solely by high salinity restrictions on distribution in the southern portion of the estuary. *Phragmites* is capable of growing throughout mesohaline salinity (up to 18 ppt; Chambers et al. 2003), and the shoreline surveyed in Virginia extended mostly through mesohaline and oligohaline sections of large tidal rivers. Interannual changes in estuarine salinity are known to influence the spread of *Phragmites* (Minchinton 2002), and salinity near the upland border often is lower than salinity in the open water of the estuary because of surface water or ground water contributions from adjacent uplands. Our data do not allow us to test for a salinity effect (i.e., we do not have information on soil salinity along the shoreline where *Phragmites* occurs), but higher salinity in the southern bay and its tributaries cannot be the cause of less shoreline occurrence of *Phragmites*.

Less *Phragmites* along Virginia shoreline could be the result of other environmental factors (e.g., warmer temperatures, nutrient limitation, fewer and more recent introduction events, more interspecific competition), but which specific factors and how they might operate alone or in concert to restrict *Phragmites* distribution is unclear. For example, *Phragmites* covers almost 50% of the more southern Mississippi River delta (White et al. 2004), so warmer temperature alone cannot be the cause of less *Phragmites* in Virginia relative to Maryland. Schaefer and Alber (2007) have shown that for Atlantic coast rivers, the percentage of watershed-derived nitrogen inputs to estuaries is significantly lower for rivers south of the Potomac River. Since *Phragmites* has large requirements for nitrogen (Windham and Meyerson 2003), its rate of spread along more southern estuarine shoreline may be limited by smaller subsidies of nitrogen from surrounding watersheds. In other words, nitrogen enrichment along entire tributaries may spur *Phragmites* expansion, versus local disturbance that facilitates initial sites of establishment. Finally, variable shoreline occupation by *Phragmites* throughout the Chesapeake Bay estuary may be

Table 2. Occurrence of *Phragmites australis* along the Virginia shoreline of Chesapeake Bay, summarized for five separate reaches around the western shore of the estuary, starting at the Maryland border (Potomac River) and extending south to the James River. Corresponding Virginia state hydrologic units are included. *Phragmites* occurrence is expressed as a percentage of shoreline with respect to four different categories of adjacent land use (km total shoreline length in parentheses).

Coastline	Hydrologic Units	% Agriculture	% Forest	% Open	% Developed	Totals
Lower Potomac River	A31–A33	4.1 (27.3)	4.5 (124)	8.6 (36.9)	2.1 (156)	3.8 (345)
Chesapeake Bay shore	C03, C08	100 (0.2)	0.7 (63.0)	3.0 (16.2)	1.2 (100)	1.3 (179)
Rappahannock River	E21–E25	1.1 (64.5)	0.5 (752)	1.7 (309)	0.5 (129)	0.8 (1255)
York River	F13, F14	0.0 (0.0)	0.0 (96.4)	0.0 (6.2)	0.0 (7.0)	0.0 (110)
James River	G08, G11, G15	0.0 (53.6)	3.9 (186)	4.7 (192)	2.7 (417)	3.3 (849)

historical artifact, and factors such as dispersal via wrack rafting (Minchinton 2006) and human facilitation of *Phragmites* introduction and expansion (Bart and Hartman 2003, Bart et al. 2006) could eventually "fill in" Virginia shoreline to the extent observed in Maryland. Although we cannot identify the influence of specific factors, the resulting pattern is that occurrence of *Phragmites* along Chesapeake Bay shoreline is more concentrated to the northeast and we suspect over time may spread out into other sections of the bay.

Phragmites is found in relative over-abundance adjacent to agricultural, forested, and open shoreline in Maryland, indicating the occurrence of *Phragmites* is substantial regardless of shoreline type. Our regression analysis for Maryland and Virginia subwatersheds, however, documented a significant positive correlation between *Phragmites* occurrence and crop agriculture in the adjacent uplands, i.e., the relative abundance of *Phragmites* varies directly with the relative abundance of agricultural land. King et al. (2007) found that the abundance of *Phragmites* was more strongly correlated with urban-suburban development in watersheds than with agricultural land use, but noted that *Phragmites* occurrence was probable where agricultural land occurred near the wetland shoreline. Our analysis of *Phragmites* occurrence and adjacent land use differs slightly from King et al. (2007). Both studies, however, support prior work indicating that human disturbance of adjacent upland may stimulate *Phragmites* invasion (Silliman and Bertness 2004, Bart et al. 2006).

In summary, the shoreline occurrence of *Phragmites* was positively correlated with agricultural land use, most extensive along the northeastern shoreline of Chesapeake Bay, and more extensive in Maryland relative to Virginia portions of the estuary. The current snapshot cannot capture the dynamics of ongoing *Phragmites* invasion and expansion in the estuary, but does indicate that current sites of establishment in Virginia are located preferentially along cleared shoreline, relative to forest or agriculture. From a management perspective, maintenance of upland buffers to minimize localized shoreline disturbance is suggested as a method to limit the invasion of *Phragmites*, with regional controls on nitrogen enrichment in the estuary to limit its subsequent spread.

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