Historic Distribution of Submerged Aquatic Vegetation (SAV) in Chesapeake Bay, MD

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INTRODUCTION

Submerged aquatic vegetation (SAV) is widely recognized as one of the most important components of a productive estuarine ecosystem. Submerged aquatic vegetation provides food and shelter for fishes and invertebrates, food for waterfowl, and positively impacts water quality through shoreline stabilization, nutrient sequestering and by facilitating the settling of suspended solids. The Chesapeake Bay estuary, like many other temperate estuaries, has exhibited dramatic declines in the abundance of SAV during the last half of the 20th century (Orth and Moore, 1983). Numerous studies suggest that increases in nutrient loading are the primary cause of these declines (Nixon 2001, Duarte 1995, Dennison and Albert, 1985; Orth and Moore, 1988). Submerged aquatic vegetation populations in Chesapeake Bay have begun rebounding in the last 20 years following widespread, chronic declines in the late 1960's and 70's (Orth et al. 1994) and acute loss in many areas due to Hurrican Agnes in 1972. As SAV abundance is used as a bioindicator of ecosystem health by the Chesapeake Bay Program, and as abundance as two dimensional area covered is the standard used to judge SAV health, it is important to have realistic expectations as to the amount of vegetation that can grow in these habitats.

The acreage of SAV visible in aerial photos taken from 1979 - 1984 was used to set the "Tier I" restoration goal for Chesapeake Bay (Batiuk et al. 1992). Subsequent interim goals are based on estimates of potential SAV habitat at <1 meter and < 2 meter water depths (the Tier II and Tier III goals, respectively). Since the goals were established, it has become apparent that for some areas, the goals depend as much upon the condition of each location between 1979 and 1984 (i.e. how degraded had it become before 1979) as they do upon how much vegetation each location could potentially support. In 1996, SAV in the tidal freshwater Patuxent River covered 100 hectares (Orth et al. 1997). This is 1,667 percent of the 6 hectare Tier I goal for this section of the river, yet only 11% of the Tier III restoration goal of 890 hectares. Tier I goals throughout the Bay range from 0 to 47% of Tier III goals for a given location.

Goals based strictly upon benthic habitat (Tier II and III) are more consistent from region to region than the Tier I goal, but assume that all areas in a given depth zone could potentially support SAV in a given year. It is recognized that natural ”exclusion zones” exist; areas where wave energy, sediment type, or other factors preclude SAV growth. These exclusion areas are not easy to define, and are only applied for a small and poorly defined portion of Chesapeake Bay. Although the concepts of what precludes SAV growth are understood, specific levels of each exclusion parameter are not. Some areas originally identified as exclusion zones by the Bay Program were found through the review of aerial photos to have once contained dense beds of SAV. Even if our understanding of these exclusion areas improves in the future, data do not currently exist to allow bay scientists to accurately predict with any precision where SAV can and cannot grow. None of the existing goals reflect what is desired- to know how much SAV actually could grow in a given area. Even in the 1950's, at a time when SAV was extremely abundant (Orth et al. 1994), Manning (1957) estimated that only about 20 to 30% of the shoals in the lower Patuxent were vegetated.

To determine historic SAV acreage, aerial photos from 1938, 1952, 1957, and 1964 were evaluated visually for Maryland’s portion of Chesapeake Bay to determine the year with the most SAV visible for each area. The photos for the year of greatest abundance in each area were then scanned, georeferenced, and photo interpreted to determine the extent of SAV beds from these years. This analysis provides an historical benchmark of a healthy SAV community in the Chesapeake Bay and provides a conservative estimate of the potential target acreage for SAV restoration.

METHODS

One thousand 9x9 black and white photographs were scanned at 300 dpi and georefrenced to State Highway Administration and stream layer rasters accurate to quad scale (1:24,000). After georeferencing, a composite image was formed on-screen that combined all photographs for each area (Figure 1). Submerged aquatic vegetation beds were traced as a vector layer at an on-screen scale of 1:12,000 directly upon the scanned images, with the original positives viewed concurrently for each photo.

As SAV beds are drawn by hand, final SAV acreage is also dependant upon decisions made in defining a "bed." Given the infinite scenarios of density and patchiness, developing a strict protocol for visual photo-interpretation is impractical. The delineator must make decisions about whether to draw a single line around several discrete patches, thus representing them as a single bed, or to make each patch it's own entity. These decisions have a substantial impact upon the final acreage estimates, and for this reason all images were interpreted by the principal investigator. One of the most critical factors is the scale of delineation; the more the image is expanded on-screen, the more likely it will be that beds are delineated individually rather than as a single bed. For this reason, on-screen scales for both photo sets were kept at 1:12,000, which provides an on-screen visual image of similar quality to the 1:24,000 photos directly interpreted by the Virginia Institute of Marine Science (VIMS) for the annual SAV survey (Orth et. Al 2001). This was done deliberately to generate similar minimum bed sizes, comparable final vectors and aid in the comparison between these photos and those interpreted by VIMS in the more recent aerial surveys.

The SAV in each photograph appears as dark patches against lighter colored sediments. The characteristic spatial heterogeneity of SAV beds makes them distinguishable from darker areas that result from deep water. Submerged aquatic vegetation beds are always patchy, and typically have very irregular edges as compared to deep-water channels. However, the deep edges of SAV beds are frequently difficult to characterize, and there are often areas where it can not be determined if the SAV bed is ending, or of the water is becoming too deep to see the plants. In every case, SAV beds are not delineated unless the patchiness is visible. This results in underestimation of the coverage of SAV in deep water areas. Many uncontrollable variables affect the effectiveness of all photo-interpretation, both historic and current surveys. These variables include water clarity, waves, sun glare, plant height, plant density, color of sediments, and timing of photography. Even when every attempt is made to minimize the effects of these variables, the total amount of SAV delineated always represents only a fraction of the actual extent of the resource.

RESULTS

Overall, 47,475.4 hectares of SAV were visible in the historic photographs in Maryland, 146% of the 32,266 hectares of total habitat that have been occupied at any time by SAV since routine photographic analysis began in 1978 (Table 1), and 154% of the 30,736.4 hectare total that sums the greatest single-year totals for SAV in each Chesapeake Bay Program (CBP) segment from 1978 through 2000.

If the areas for which historic coverage is complete and the acreage of SAV is greater than 10 hectares are totaled, these 31 CBP segments (Table 2) show the historic total of 43,629.7 hectares nearly doubles both the Tier I total of 26,971 hectares and the best single year sum total of 25,197 hectares. Only five of these thirty-one CBP segments (Figure 3) have had more SAV visible since 1978 than in the pre-1972 historic photos (BOHOH, CB3MH, ELKOH, GUNOH, POCMH). This has the potential to significantly underestimate SAV coverage in a year, as it is possible that the historic SAV acreage is from years in which SAV wasn't abundant in a given area, or that the water clarity was too poor to discern all the SAV that was present. In contrast, eleven of the 31 CBP segments (Figure 4) have always supported less than 25% of the historic acreage for any single year (CB4MH, CHOOH, CHOMH2, CHSOH, FSBMH, MANMH, NORTF, PATMH, PAXMH, RHDMH, SOUMH). Unfortunately, many tidal freshwater segments have no historic photos of suitably quality for analysis. Areas for which historic SAV acreages will not be possible include the Patuxent, Potomac, and upper Choptank rivers. Many photos for these areas were reviewed, and some had very small amounts of SAV, but none had enough coverage to justify photo delineation. As these photos were reviewed, the SAV acreage is reported as zero (Table 1).

In the segments for which complete coverage was obtained historically, an average of 35% of the available habitat was vegetated at depths of less than one meter (Table 4). Variation from segment to segment was high, and ranged from a low of 3% in Fishing Bay (FSBMH) to a high of 75% in the Susquehanna Flats area (CB1TF). From 1 to 2 meters deep, only 10% of available habitat contained visible SAV beds, with a low near

0% in several segments and a high of 23% in the lower central Chesapeake Bay (CB5MH)(Table 3).

Conclusions

Of the 31 segments with with complete historical coverage and greater than 10 hectares of SAV (Table 2), CB4MH, CHOOH, CHOMH2, CHSOH, FSBMH, MANMH, NORTF, PATMH, PAXMH, RHDMH, SOUMH appear to be among the least healthy SAV communities. These areas would be good candidates to be targeted for water quality improvements and/or restoration

Of the 31 segments with complete historical coverage and greater than 10 hectares of SAV (Table 2), BOHOH, CB3MH, ELKOH, GUNOH, and POCMH are the segments that appear to be the healthiest in the Bay today. These areas should be considered benchmarks against which to measure the progress of other areas in Chesapeake Bay.

Literature Cited

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Table 1. Hectares of SAV by CBP segment

	Tier 1 Goal (hectares)	SingleYear Max (SYM) 1978-2000	Year of SYM	Historic SAV (hectares)	Year(s)	Comments
BACOH	0.0	0.0	NA	0.0	1964	No SAV visible in photos
BIGMH	364.5	238.3	2000	917.0	1952	
BOHOH	17.3	75.7	2000	20.9	1964	
BSHOH	23.4	78.7	2000	95.6	1952	
C&DOH	0.6	0.6	1978	0.0	NA	No SAV visible in photos
CB1TF	3,112.2	3,143.5	2000	7,266.5	1957, 1964	Big central SAV bed extrapolated
CB2OH	267.0	285.4	2000	409.1	1964, 1952	
CB3MH	697.6	554.8	1978	354.9	1964, 1957	
CB4MH	152.0	102.6	1978	1,143.8	1937, 1952	
CB5MH(MD)	1,933.2	1,666.8	1992	3,623.6	1952	
CHOMH1	2,990.4	2,792.6	1997	3,533.1	1952	
CHOMH2	187.0	94.3	1978	818.6	1952,1937	
CHOOH	0.0	0.0		35.9	1952, 1937	
CHOTF	0.0	0.0		0.0		No SAV visible in photos
CHSMH	1,517.8	1,050.3	1978	1,536.2	1957, 1952	
CHSOH	0.0	0.0		47.4	1957	
CHSTF	0.0	0.0		0.0		No SAV visible in photos
EASMH	2,479.0	2,005.4	1999	2,591.7	1952, 1937	
ELKOH	447.3	692.1	2000	112.6	1964, 1957	
FSBMH	13.4	25.9	1994	295.7	1952	
GUNOH	350.2	984.6	2000	778.2	1964	
HNGMH	1,599.1	1,845.4	1993	3,563.9	1952	
LCHMH	616.4	648.8	1999	1,677.5	1952	
MAGMH	236.7	141.2	1978	289.9	1938, 1952	1952 for Gibson Island area
MANMH	276.2	182.7	2000	1,806.0	1952	
MATTF	54.3	133.8	2000	9.8	1937	Area not completed, photos not available
MIDOH	347.5	299.6	2000	369.0	1964	
NANMH	0.0			2.6	1938	
NANOH	0.0			5.2	1938	
NANTF	0.0			0.0		No SAV visible in photos
NORTF	7.5	???		66.4	1957	
PATMH	50.2	49.0	1978	237.2	1957	
PAXMH	143.6	53.7	1985	1,030.0	1952, 1938	
PAXOH	0.8	46.7	2000	20.3	1952	No SAV visible in photos
PAXTF	5.6	63.9	1996	0.0		No SAV visible in photos
PISTF	337.8	319.4	1987	0.0		Area not completed, photos not available
POCMH(MD)	840.8	664.8	1994	369.7	1952, 1937	
POCOH	0.0			0.0	1952	No SAV visible in photos
POCTF	0.0			0.0	1952	No SAV visible in photos
POTMH(MD)	400.1	951.2	1999	2,998.1	1952	Area not completed, photos not available

Table 1. Hectares of SAV by CBP segment (continued)

POTOH(MD)	1,725.8	1,742.5	1998	413.0	1937	Area not completed, photos not available
POTTF(MD)	2,591.9	1874.7	1991	393.6	1937	Area not completed, photos not available
RHDMH	5.9	5.9	1978	39.8	1952	
SASOH	164.7	388.6	2000	0.0		Area not completed, photos not available
SEVMH	187.8	133.8	1978	143.6	1938	
SOUMH	20.6	22	1998	223.7	1952	
TANMH(MD)	8,053.1	7330.4	1992	10,095.4	1952, 1938	not complete, SAV extends beyond photos
WICMH	0.0			3.0	1952	
WSTMH	46.8	46.7	1978	136.8	1952	
Total	32,266.1	30,736.4		47,475.4		

Table 2. Hectares of SAV for CBP segments with complete historical coverage and >10 hectares

	Tier I	best year 1978-2000	Historic
BIGMH	364.5	238.3	917
BOHOH	17.3	75.7	20.9
BSHOH	23.4	78.7	95.6
CB1TF	3,112.20	3,143.50	7,266.50
CB2OH	267	285.4	409.1
CB3MH	697.6	554.8	354.9
CB4MH	152	102.6	1,143.80
CB5MH(MD)	1,933.20	1,666.80	3,623.60
CHOMH1	2,990.40	2,792.60	3,533.10
CHOMH2	187	94.3	818.6
CHOOH	0	0	35.9
CHSMH	1,517.80	1,050.30	1,536.20
CHSOH	0	0	47.4
EASMH	2,479.00	2,005.40	2,591.70
ELKOH	447.3	692.1	112.6
FSBMH	13.4	25.9	295.7
GUNOH	350.2	984.6	778.2
HNGMH	1,599.10	1,845.40	3,563.90
LCHMH	616.4	648.8	1,677.50
MAGMH	236.7	141.2	289.9
MANMH	276.2	182.7	1,806.00
MIDOH	347.5	299.6	369
NORTF	7.5	7.5	66.4
PATMH	50.2	49	237.2
PAXMH	143.6	53.7	1,030.00
POCMH(MD)	840.8	664.8	369.7
RHDMH	5.9	5.9	39.8
SEVMH	187.8	133.8	143.6
SOUMH	20.6	22	223.7
TANMH(MD)	8,053.10	7330.4	10,095.40
WSTMH	46.8	46.7	136.8
Total	26,971.1	25,196.6	43,334.0

Table 3. Historical SAV distribution by depth (mean low water) for each CBP segment (percentage)

Cbpseg	<1 meter	1-2 meters	>2 meters
BIGMH	64.3	28.4	7.3
BOHOH	96.9	2.8	0.3
BSHOH	97.2	2.8	0.0
CB1TF	80.0	18.0	2.1
CB2OH	71.1	27.1	1.8
CB3MH	77.6	16.4	6.0
CB4MH	38.1	51.7	10.2
CB5MH	47.4	48.8	3.8
CHOMH1	60.2	33.0	6.7
CHOMH2	77.8	20.3	1.9
CHOOH	92.9	1.6	5.5
CHSMH	73.5	23.6	2.9
CHSOH	95.3	4.3	0.4
EASMH	62.0	34.4	3.6
ELKOH	88.3	11.3	0.4
FSBMH	60.4	39.2	0.4
GUNOH	37.6	60.7	1.7
HNGMH	80.8	16.7	2.5
LCHMH	69.8	28.2	2.0
MAGMH	72.0	19.5	8.5
MANMH	68.5	30.5	0.9
MATTF	98.2	1.8	0.0
MIDOH	61.0	34.0	4.9
NANMH	100.0	0.0	0.0
NANOH	88.6	3.9	7.5
NORTF	71.8	28.1	0.1
PATMH	60.7	29.2	10.1
PAXMH	38.6	47.1	14.3
POCMH	96.3	3.7	0.0
POTMH	76.2	17.5	6.3
POTOH	92.8	7.0	0.2
POTTF	14.7	30.5	54.8
RHDMH	75.4	22.7	2.0
SASOH	0.3	76.1	23.7
SEVMH	66.9	20.8	12.3
SOUMH	74.4	16.9	8.7
TANMH	55.2	38.4	6.4
WICMH	97.2	2.8	0.0
WSTMH	96.0	3.8	0.1

Table 4: Percentage of potential SAV habitat that is vegetated

Cbpseg	Tier II habitat (hectares)	Hectares of SAV (<1m)	% vegetated	Tier III habitat (hectares)	Hectares of SAV (1 to 2 m)	% vegetated
BIGMH	1,360.2	581.0	42.7%	2,120.1	256.6	12.1%
BOHOH	464.6	16.8	3.6%	773.9	0.5	0.1%
BSHOH	820.6	89.6	10.9%	1,846.8	2.6	0.1%
CB1TF	5,714.6	4,258.3	74.5%	10,749.2	955.9	8.9%
CB2OH	2,289.8	286.6	12.5%	4,270.2	109.1	2.6%
CB3MH	1,774.0	257.7	14.5%	3,596.8	54.5	1.5%
CB4MH	4,111.4	439.1	10.7%	10,227.6	595.4	5.8%
CB5MH	3,517.5	1,743.0	49.6%	7,658.1	1,791.8	23.4%
CHOMH1	5,347.1	2,086.9	39.0%	8,549.4	1,143.9	13.4%
CHOMH2	1,640.7	615.8	37.5%	2,877.4	160.6	5.6%
CHOOH	506.7	27.7	5.5%	690.2	0.5	0.1%
CHSMH	2,786.7	1,069.5	38.4%	4,611.0	343.3	7.4%
CHSOH	715.6	36.3	5.1%	973.0	1.7	0.2%
EASMH	5,268.8	1,584.7	30.1%	8,485.6	877.8	10.3%
ELKOH	1,013.5	91.5	9.0%	1,911.0	11.7	0.6%
FSBMH	5,954.4	177.0	3.0%	8,667.2	115.0	1.3%
GUNOH	1,063.3	286.9	27.0%	2,886.0	463.0	16.0%
HNGMH	4,255.5	2,627.2	61.7%	6,612.3	543.4	8.2%
LCHMH	3,561.2	1,145.6	32.2%	5,448.0	463.3	8.5%
MAGMH	620.0	199.7	32.2%	908.8	54.0	5.9%
MANMH	3,189.2	1,207.5	37.9%	4,798.1	538.3	11.2%
MIDOH	568.2	210.1	37.0%	991.5	117.2	11.8%
NORTF	402.1	47.5	11.8%	1,135.1	18.6	1.6%
PATMH	997.9	125.5	12.6%	1,944.5	60.3	3.1%
PAXMH	1,819.9	305.4	16.8%	3,242.6	373.1	11.5%
POCMH	1,390.5	336.1	24.2%	3,193.8	13.0	0.4%
RHDMH	248.5	23.0	9.3%	432.7	6.9	1.6%
SEVMH	532.6	90.9	17.1%	803.4	28.2	3.5%
SOUMH	562.2	151.4	26.9%	883.4	34.5	3.9%
TANMH	10,057.5	5,546.4	55.1%	19,841.3	3,862.6	19.5%
WSTMH	446.7	125.4	28.1%	651.6	5.0	0.8%
TOTAL	73,001.6	25,790.1	35.3%	131,780.5	13,002.5	9.9%

Table 5: Metadata

File Name:	Varies: named for individual photo by flight line and photo group
Originating Organization:	Photos digitally processed by Towson University Center for GIS
Description of Data Set:	Georeferenced Historical Aerial Photos
Status of Data Set:	
Geographic Area Covered & Bounding Coordinates:	Chesapeake Bay Area Shoreline 75 30' W to 77 30'W by 38 00' N to 39 45' N (approximate: varies by individual photo group).
Data Layer Theme:	Historical Aerial Photos
Key Words:	aerial photo, historic
Contact Person:	Mike Naylor
Contact Phone #:	(410) 260-8652
Contact e-mail:	mnaylor@dnr.state.md.us
Project:	Georeferencing of Historical Aerial Photographs for use in studying the Historical Distribution of submerged aquatic vegetation in the Chesapeake Bay.
Format of Data:	Georeferenced tif files with accompanying world files
Software & Version:	Arc/Info v7.2.1
File Size:	Varies by image (approximately 8MB each).
Type of Source Material:	9x9 aerial photos
Scale of Source Material:	1:24,000
Date(s) of Source Material:	Varies by image (most taken during 1950's with some before and some after this period).
Method of Data Collection:	
Method of Digital Production:	Scanned aerial photos converted to tif images, georeferenced using Maryland SHA road and stream files (1:24000).
Accuracy Report:	Data only accurate as original photos permit with additional consideration given for accuracy of Maryland SHA data used to reference images.
Geographic Divisions:	Approximately 3.8 square miles per image.
Type of Data:	Raster
Coordinate System, Units and Datum:	NAD 83 Meters Maryland State Plane Zone #4126
Attribute Description:	N/A
Available Media:	
Distribution Information:	Questions on distribution and access should be addressed to Mike Naylor at Maryland Department of Natural Resources.
Access/Use Liability & Constraints:	Questions on distribution and access should be addressed to Mike Naylor at Maryland Department of Natural Resources.

Figure 1: Photos used for SAV bed delineations

Figure 2: Chesapeake Bay Program Segments

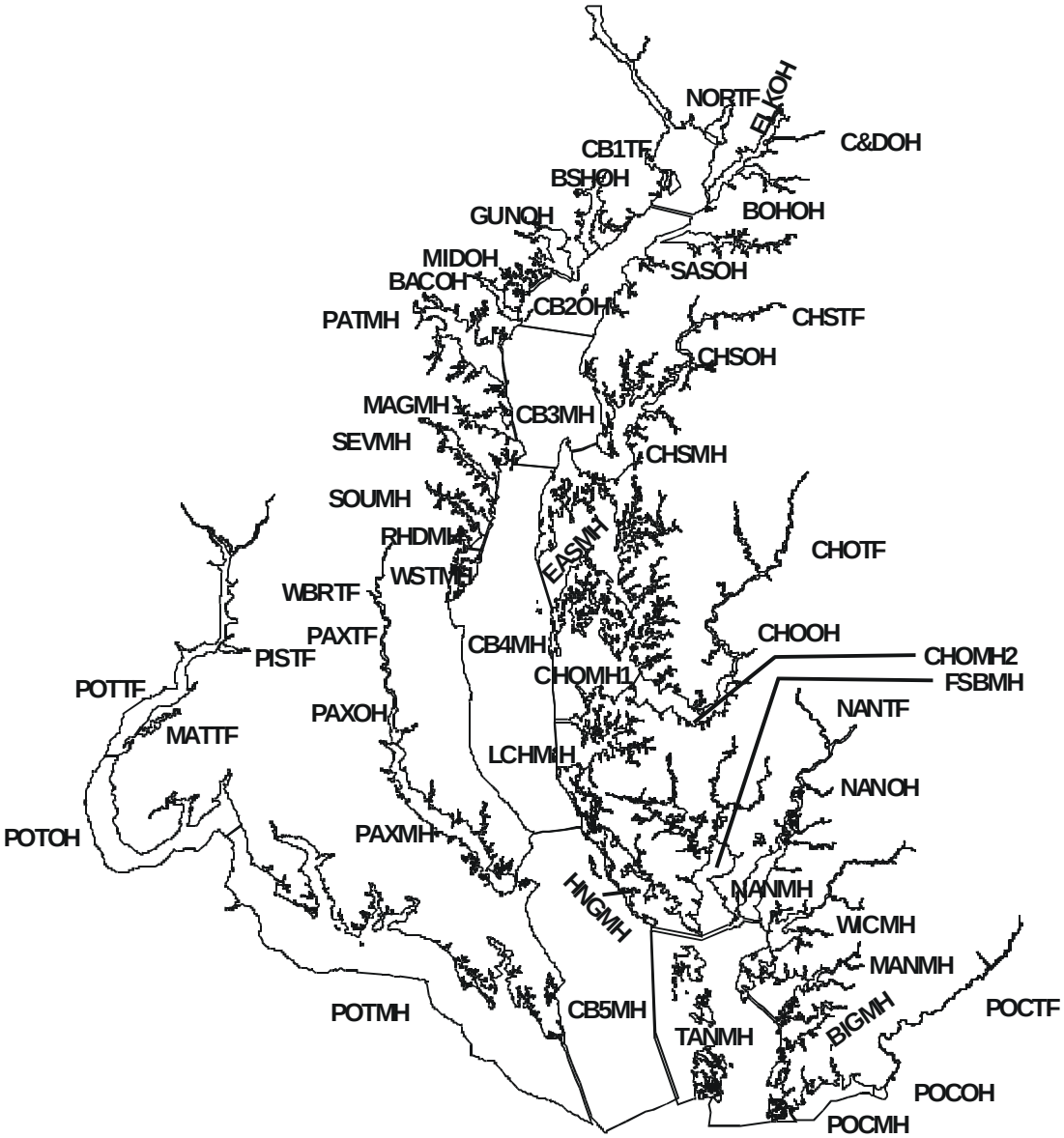

Figure 3: Chesapeake Bay Program Segments with more SAV from 1978-2000 than historically

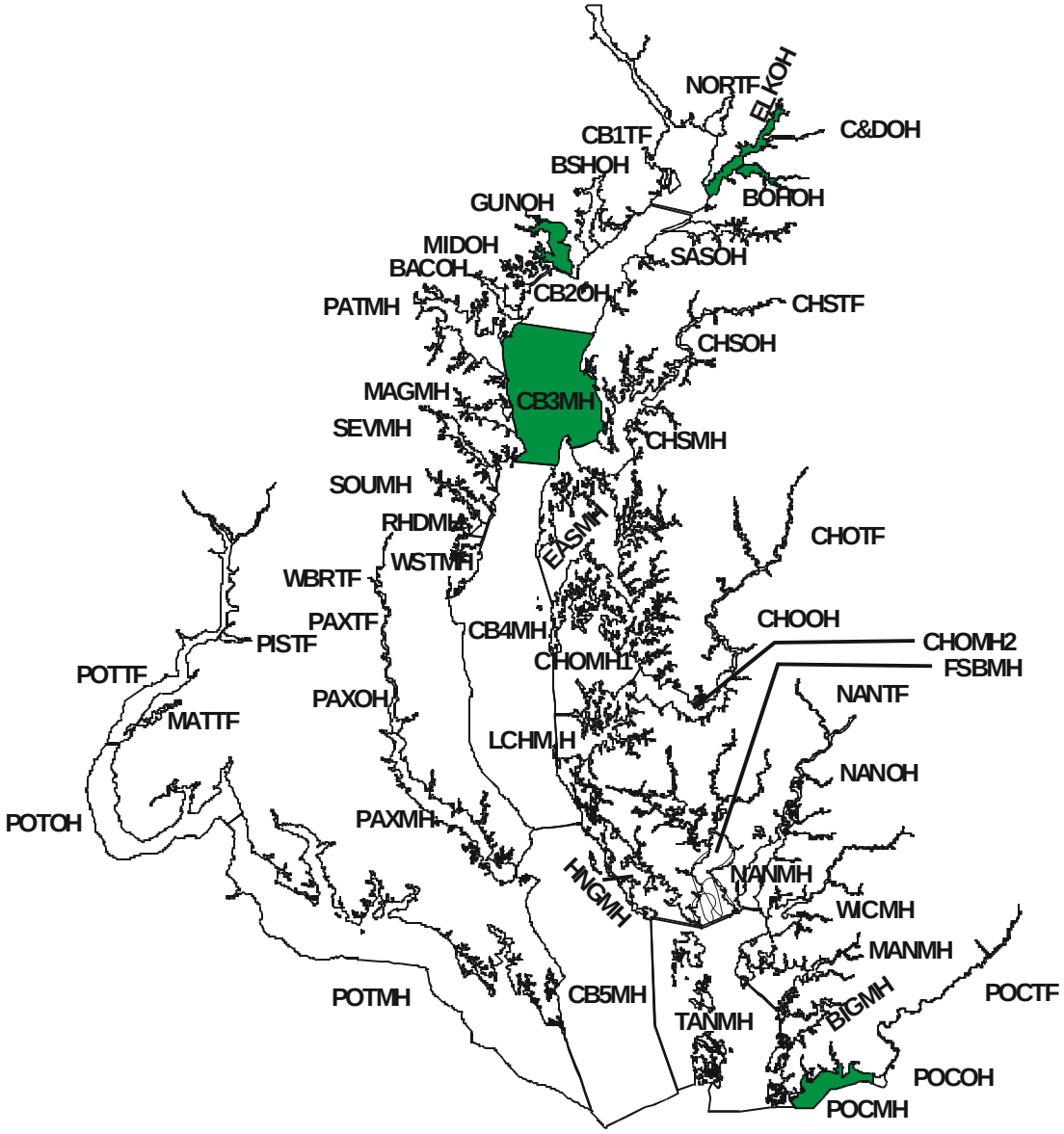

Figure 4: Chesapeake Bay Program Segments with less SAV from 1978-2000 than historically