ANALYSIS OF HISTORICAL DISTRIBUTION OF SUBMERGED AQUATIC VEGETATION (SAV) IN THE JAMES RIVER

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by

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Summary

Analyses of historical photography and ground surveys dating from the 1930s indicate that approximately 1645 hectares of SAV have been historically present in shallow water regions throughout the James River. This compares to 77 hectares of vegetation reported in 1997 and a James River Tier I SAV restoration goal of 107 hectares (areas mappped with SAV from 1971-1991). Overall, the temporal and spatial patterns of loss of SAV populations in the James River suggest declines occurred first in the tidal freshwater regions of the upper James beginning approximately 50 years ago, and then subsequently in the lower James beginning approximately 30 years ago. Since then regrowth has been limited to high salinity regions near the river's mouth along the shoreline of Hampton and Newport News, and an apparent increase in the region of the Chickahominy River. In a series of surveys by boat during the summer of 1998, numerous beds of SAV, many too small to map with high altitude aerial photography, were found in a number of the tidal tributary creeks of the James including the Chickahominy River, Wards Creek, Upper Chippokes Creek, Grays Creek, and Lower Chippokes Creek, as well as along the Hampton-Newport News shoreline. The SAV which occurs in the river system today was found to be dominated by three species. SAV in the tidal freshwater tributaries of the upper James consistes principally of *Ceratophyllum demersum* (coontail) and *Najas minor* (common naiad). Here the SAV was growing to depths of 0.5-1.5 m. The SAV in the high salinity region is the saltwater tolerant species *Zostera marina* (eelgrass). Water depths of the areas currently vegetated with eelgrass were found to be approximately 0.5 to 1.0 m at MLW, while historical photographs suggest that vegetation in the lower James formerly grew to depths of nearly 2.0 m.

Background

Throughout most regions of the Chesapeake Bay and its tributaries both direct and anecdotal evidence has indicated that recent, large-scale declines of submerged aquatic vegetation (SAV) occurred in the late 1960s and early 1970s (Orth and Moore 1983a). These declines have been related to increasing amounts of nutrients and sediments in the bay system resulting from development of the bay's shorelines and watershed (Twilley et al. 1985). Currently there are approximately 28,000 hectares (69,000 acres) of SAV in Chesapeake Bay (Orth et al. 1998). Although it has been estimated that this is approximately 10% of the bay's historical SAV distribution, most comprehensive analyses have been based on 1971 or later aerial photography and the distributions of SAV prior to this time in many regions are not well known.

SAV is a highly valuable resource whose presence serves as an important indicator of local water quality conditions (Dennison et al. 1993). SAV growth and survival can be decreased by high levels of turbidity and nutrient enrichment, and because SAV beds are non-motile their presence serves as an integrating measure of variable water quality conditions in local areas (Dennison et al. 1993; Moore et al. 1996). Water quality requirements for SAV growth are particularly crucial as barometers of the health of the Chesapeake Bay environment because unlike restoration requirements developed for various species of fish and shellfish that involve changes in both environmental quality and management of human harvesting activities, SAV restoration is more directly related to water quality.

Because of the direct relationships between SAV and water quality, trends in the distribution and abundance of SAV over time are also very useful in understanding trends in water quality. Review of photographic evidence from a number of sites dating back to 1937 suggests that SAV, once abundant throughout the Chesapeake Bay system, have declined from historic levels and may therefore indicate a similar deterioration of water quality conditions has occurred (Orth and Moore 1983a).

The growth of SAV in many areas may, however, be limited by factors unrelated to water

quality. For example, areas with high currents and wave activity, or sites where sediments are very high in organic content may not be suitable for SAV growth (Barko and Smart 1986). Therefore targets for the geographical limits of SAV restoration have been based on documented evidence of previous SAV growth in the region since 1971 (Batiuk et al. 1992). However, we lack comprehensive knowledge of the historical, pre-1971 levels of SAV in Virginia's tributaries and in regions such as the James River, where there had been some anecdotal suggestions that SAV declines may have begun prior to 1970. Therefore, current SAV restoration targets for the James and other Virginia Rivers may underestimate the potential for SAV recovery. To develop more precise SAV restoration targets for the James River and to formulate the strategies for achieving these targets, it is necessary to identify the potential for SAV restoration as precisely as possible. Identification of those areas with previous evidence of SAV growth is an important step in quantifying that potential. In particular, because of a need to develop and implement management strategies for the James River, knowledge of the full potential for SAV recovery in this region is important.

SAV communities are particularly suitable for identification through analysis of aerial photography from a variety of sources (Orth and Moore 1984). Although estuarine waters can be quite turbid, SAV are generally found growing in littoral areas where depths are less than one meter and their photographic signatures can be identified by experienced photointerpreters. While the absence of SAV on historical aerial photographs does not necessarily preclude SAV occurrence, SAV signatures are strong supporting evidence for the previous occurrence of SAV (Orth and Moore 1983b).

Objectives of Study

This study was undertaken to develop a comprehensive understanding of the historical distribution of SAV in the James River starting approximately 60 years ago, when aerial photographic surveys first became available. Specific objectives included:

1) To search photoarchives for imagery of the littoral zones in the tidal portions of the

James River for evidence of SAV.

2) To delineate and map the changing SAV distributions in these regions at 10 to 20 year intervals, dependent upon image availability.

3) To develop a preliminary evaluation of the currently reported SAV distribution relative to the historical distribution using ground surveys.

4) To display and quantify the SAV distributions using a computer-based geographic information system (GIS) and to summarize the results in report form.

Methods

1998 Ground Survey

A series of surveys of the littoral zone along the James River were conducted in August and October 1998, using small boats to determine the current presence or absence of SAV. A range of sites were investigated, which either demonstrated evidence of SAV in the past, or had the potential for current SAV growth, but because of their size might be too small for identification or delineation on current or historical aerial photography. These included sites within many of the small tidal creeks which occur along the river. Each site was sampled by dragging the bottom with a rake at several locations to collect bottom material, including any SAV. Other ancillary information was recorded including water depth, and at some sites, secchi depth, bottom type, and salinity. Sites were chosen based upon general knowledge of SAV occurrence in other systems, evidence of the potential for SAV based upon 1998 photography, evidence of previous occurrence in historical photography, or observations made during a low level (1000 ft. altitude) reconnaissance flight flown in June, 1998.

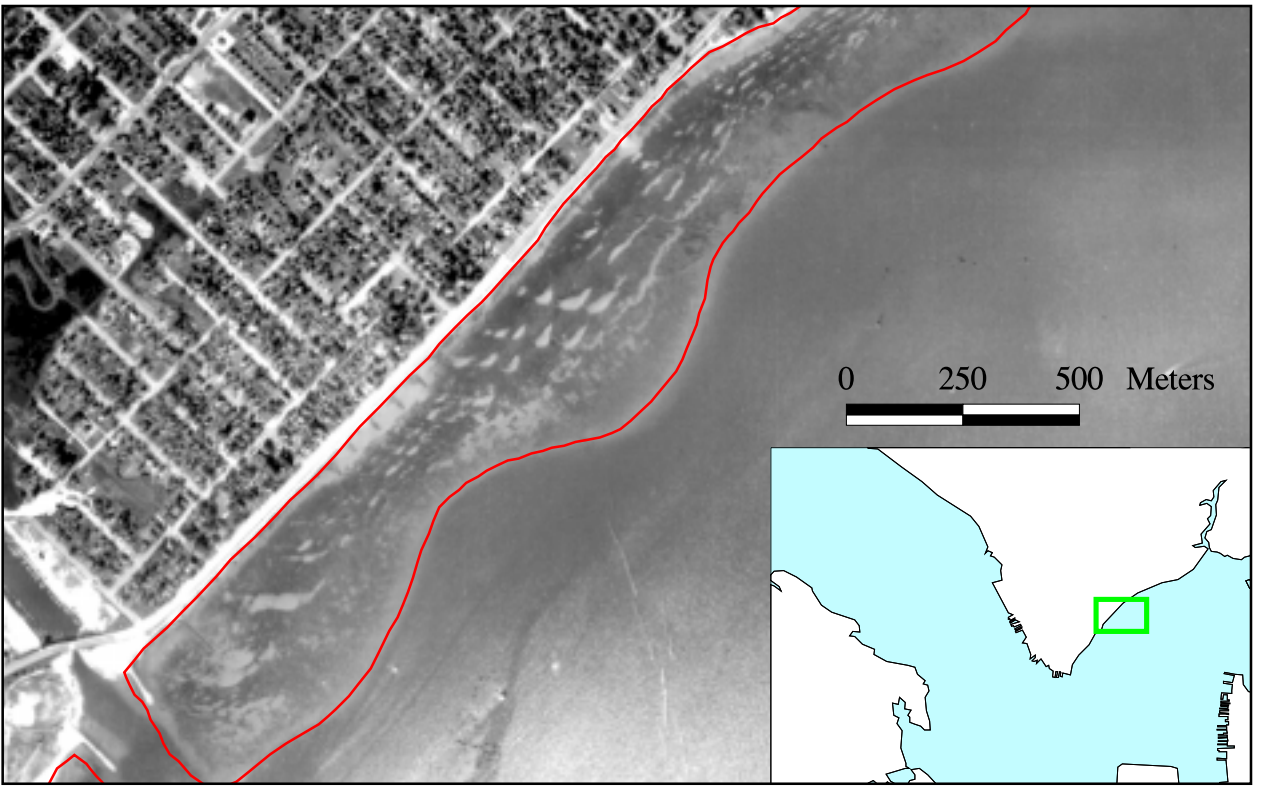
Historical Survey

Key photographic databases including Va. Department of Transportation (VDOT), National Oceanic and Atmospheric Administration (NOAA), United States Department of Agrilculture (USDA), United States Geological Survey (USGS), and the Virginia Institute of Marine Science (VIMS) archives as well as other published reports were searched for photography and other

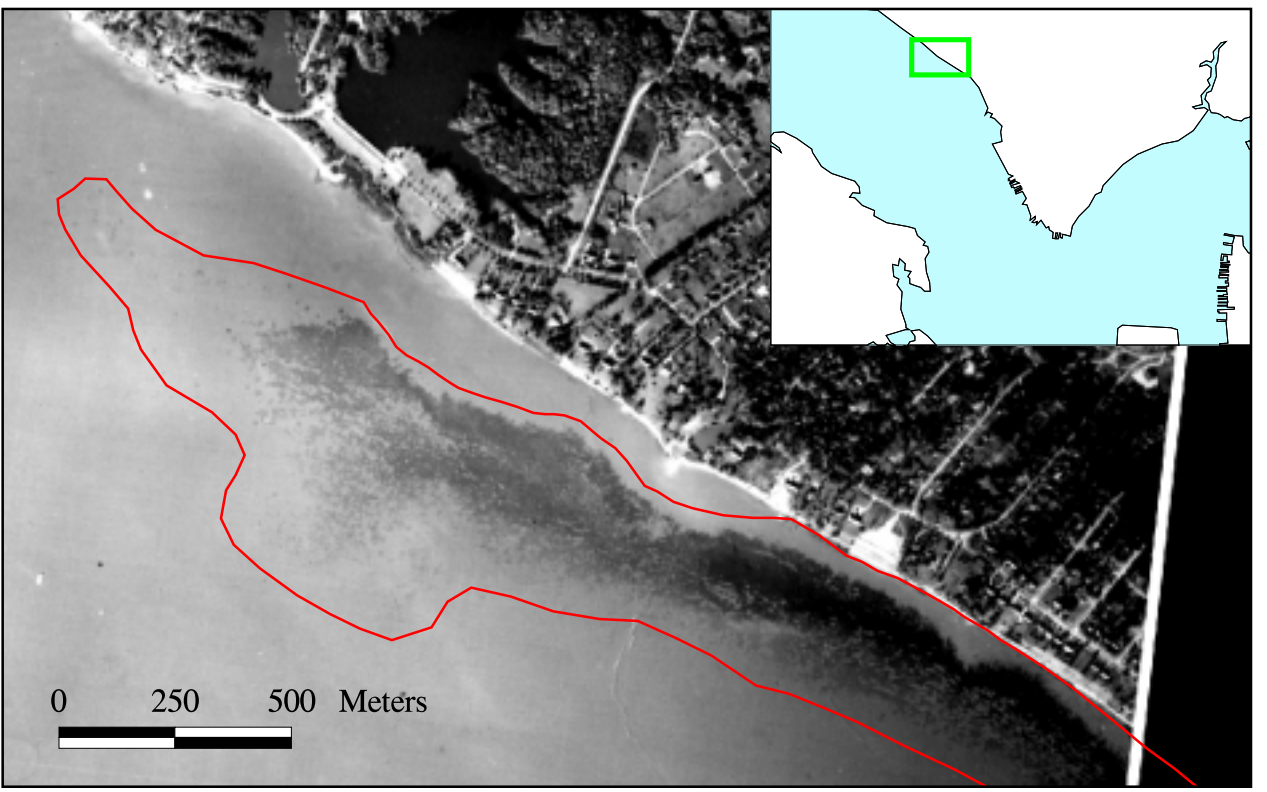
information relative to SAV occurrence in the James River. Telephone contacts were made as necessary and databases were searched by direct visit to evaluate paper prints and color transparencies. Photographs which contained images of SAV were scanned and brought into the GIS as described below. Web-based USGS and NOAA databases were also searched online using an Internet web browser. NOAA, National Ocean Survey (NOS) Nautical Charts were also found to have SAV ground survey information which was obtained including copies of original survey sheets.

Photointrepretation of the aerial photographs followed as closely as possible the methods currently used to delineate SAV beds throughout the Chesapeake Bay in annual aerial SAV surveys (eg. Orth et al. 1998). Generally, high salinity SAV beds which may have occurred in regions of the James River, where salinities are typically above 10 ppt, can be identified in the shallow, nearshore regions by their characteristic bottom patterns and reflectance signatures. These patterns are similar to beds currently found in other regions of the lower bay and other Virginia rivers such as the York. Figure 1 illustrates typical historical SAV signatures from high salinity beds along the cities of Hampton and Newport News shorelines, on photography that was taken in April of 1953. Maximum seasonal biomass of high salinity SAV in this region would have occurred in late May or in early June, therefore these images depict the vegetation near maximum standing crop. Low salinity and freshwater SAV beds generally have much darker signatures which can sometimes be confused with other bottom features. However, low salinity and freshwater SAV beds still occur in many regions of the Maryland portion of the upper Chesapeake Bay as well as some Maryland tributaries including the Potomac River. These similar areas serve as useful guides for photointrepretation of historical photography of the upper James River. Historical ground survey information, both qualitative and quantitative, of SAV in the James River may sometimes be necessary to accurately determine whether the patterns exhibited on the photography are actually those of SAV beds. In the case of the freshwater, tidal James many of the SAV beds depicted in the historical imagery taken in 1937 were also delineated on bathometric surveys undertaken by

Figure 1. Characteristic high salinity SAV (eelgrass) bed signatures from USDA historical photography (1953) taken along the Hampton (top frame) and Newport News (bottom frame) shorelines.



Dense eelgrass beds offshore of Chesapeake Avenue (1953)



Sparse eelgrass beds near Lake Maury (1953)

the United States Coast and Geodetic Survey (USC&GS) in 1948. Figure 2 illustrates characteristic SAV signatures on aerial photos of the tidal freshwater James near Hopewell, taken in April, 1937. Maximum seasonal biomass for freshwater SAV species typically occurrs in late summer, therefore these images depict sparse, early season growth.

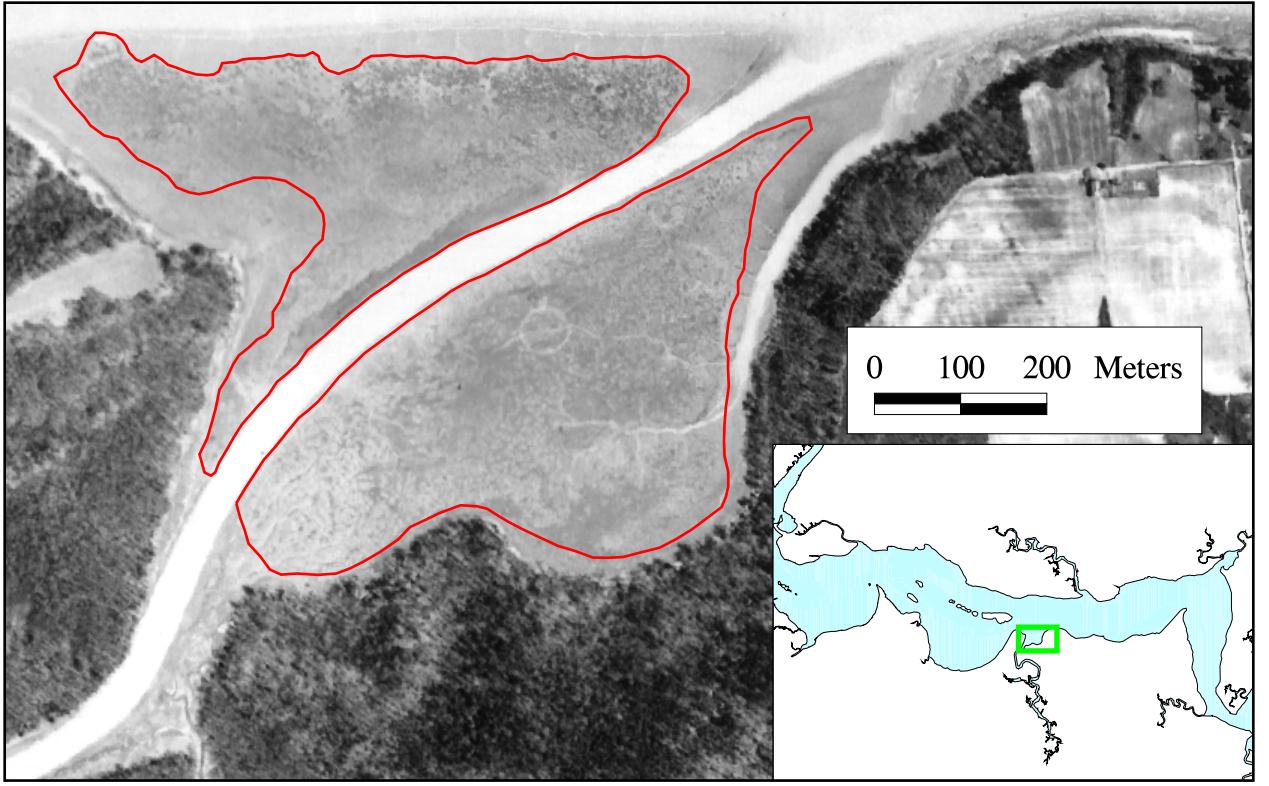
Initial screening of photographic prints was accomplished by viewing under 10X magnification viewer. Each print was searched for potential SAV signatures, and the quality of the imagery for SAV delineation was estimated as “Good”, “Fair”, or “Poor.” Those prints that showed some evidence of SAV signatures were scanned at a resolution of 300 DPI and viewed using Adobe Photoshop™.

The aerial photography that was determined to have SAV signatures was processed using a heads-up, on-screen digitizing system. The system improves accuracy by combining the series of images into a single geographically registered image permitting the final SAV interpretation to be completed seamlessly in a single step. In addition, the images are available digitally and can be printed along with the interpreted lines to show the precise character of the SAV beds.

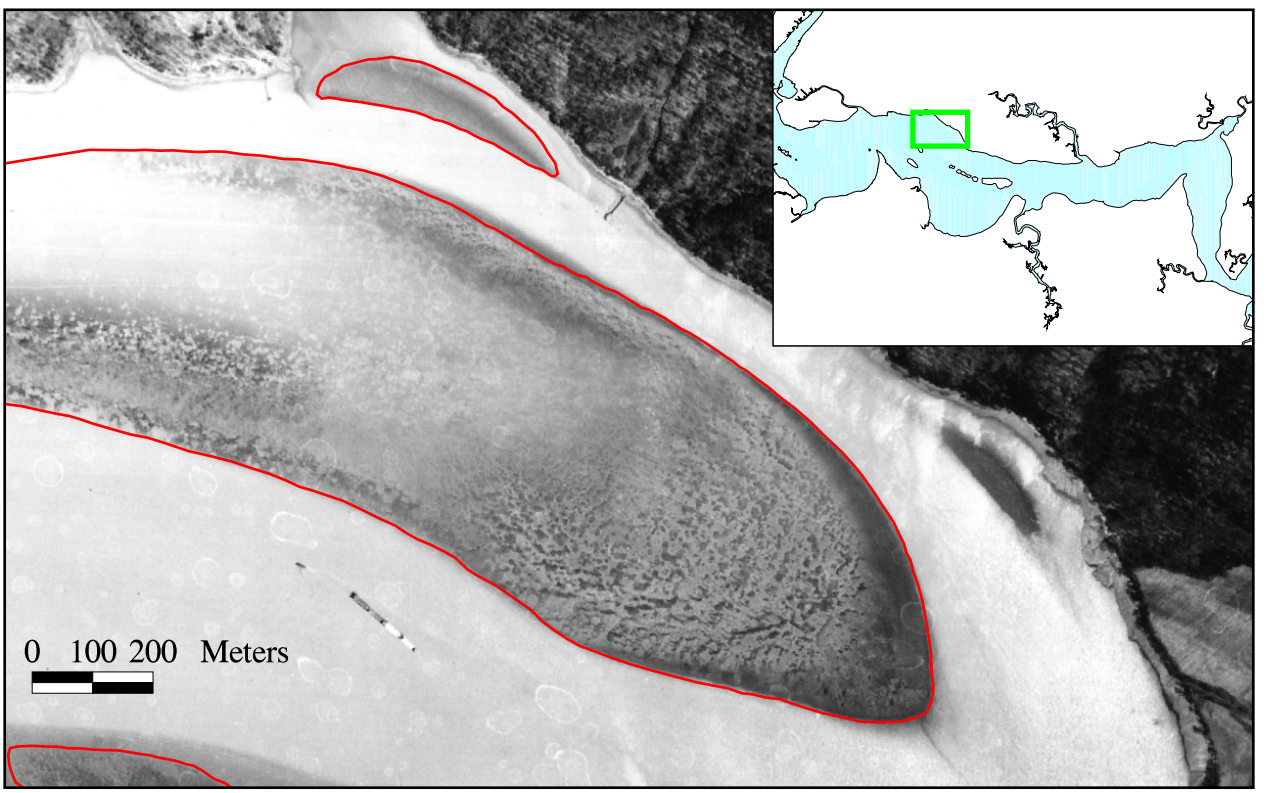
The 10 in. x 10 in., black and white aerial photographs which were scanned at a resolution of 300 dpi, formed pixels approximately 1.7 meters in width. This was the minimum resolution required to accurately delineate SAV beds and resulted in files that were approximately 10 megabytes in size. The scanned images were transferred to a Unix workstation for registration using ARC/INFO GIS software (ESRI, Redlands, Calif.).

A preliminary registration was performed using USGS 1:100,000 scale DLG road and hydrology data. This rough orientation of the images facilitated the identification and selection of control points for each photo. Six to eight control points were distributed evenly over the area covered by the photo and were selected to be clearly identifiable both on the photo and on the USGS 1:24,000 scale topographic quadrangle. Each control point was marked on a clear mylar copy of the USGS quadrangle and digitized into the GIS using an Altek digitizer. Matching points

Figure 2. Characteristic freshwater SAV bed signatures from USDA historical photography (1937) taken at the mouth of Powell Creek (top frame) and shallow subtidal flats near Hopewell (bottom frame).



SAV beds in Powell Creek (1937)



SAV beds in the James River near Hopewell (1937)

were identified on the image using the ARC/INFO register command. A separate affine transformation was computed for each image based on the control points and was applied to rectify the image to a UTM map projection. The RMS error for the transformation varied among images from 2.6 meters to 4.1 meters with a mean of 3.5 meters. The rectified images were then merged to form a single image for interpretation.

SAV bed outlines were traced directly from the combined image displayed on the computer screen into a GIS polygon file. The interpreted boundaries were drawn to include all visible SAV areas regardless of patchiness or density.

Results

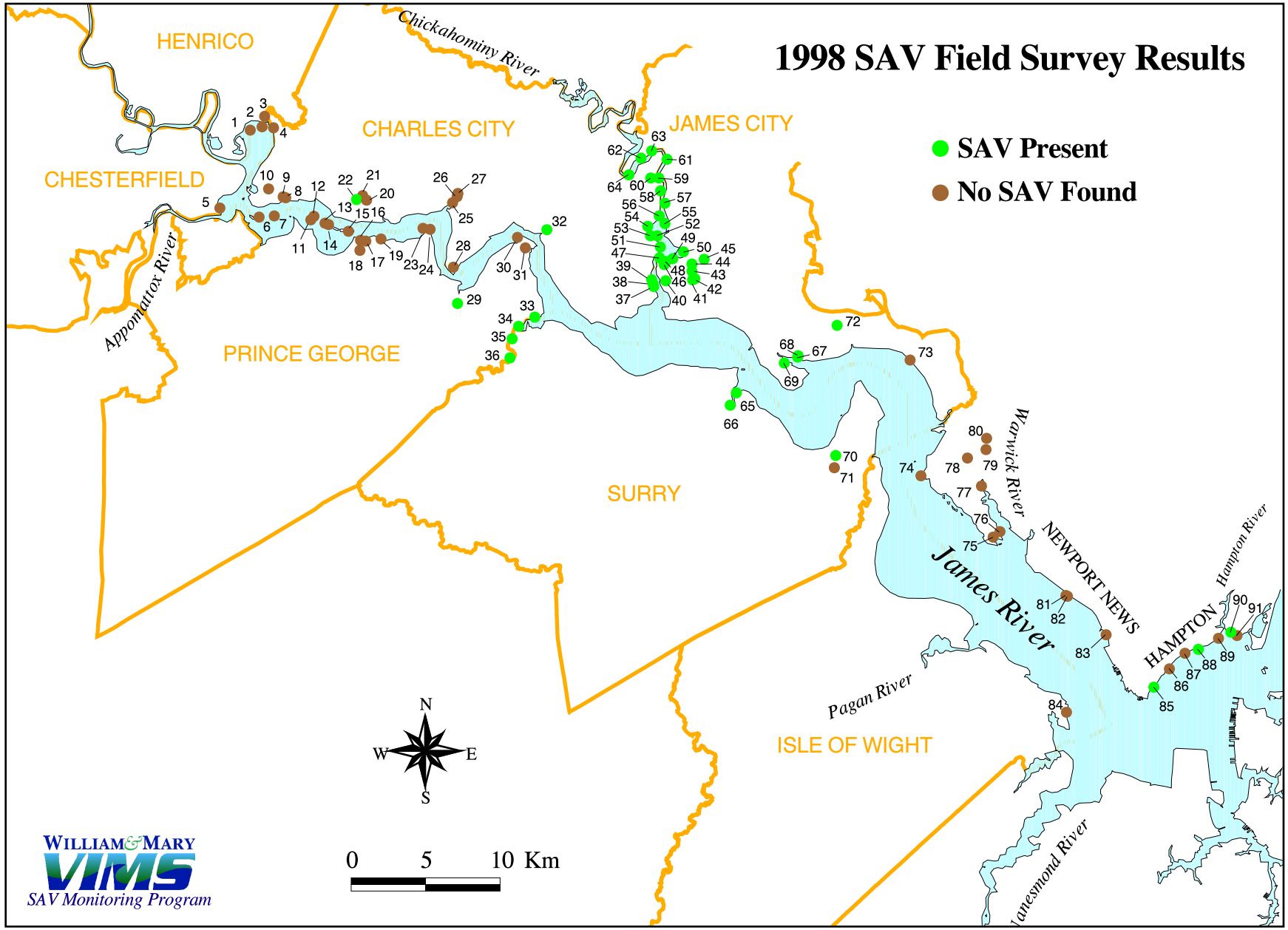
1998 Ground Survey

The SAV ground survey revealed the occurrence of SAV in several smaller creeks and tributaries of the James River in the region of the Chickahominy River as well as along the northern shoreline of the lower James in Hampton Roads. Ground survey locations indicating either the presence or absence of SAV are depicted in Figure 3. Longitude and latitide of specific locations, SAV species present, and other observations are presented in Appendix A.

Hopewell Region

Shallow sub-tidal flats (usually 0.5m in depth or less) along the river shoreline and surrounding the many mid-channel islands in the Hopewell region of the James (ie. Curles Neck and Presque Isle Refuge to Windmill Point) were found to be unvegetated (Fig. 3). Most areas consisted of soft mud bottom, or mud mixed with organic matter. Occasionally some small patches of SAV were found at the heads of several of the small tributaries including Herring, Wards and Kennon creeks. This consisted typically of coontail (*Ceratophyllum demersum*) or common elodea (*Elodea canadensis*). No areas upriver of Curles Neck were field checked, since a preliminary overflight of the region in June of 1998 by small plane at an altitude of 1000 ft. revealed no evidence of SAVin this area. Small fringing beds, such as those which occurred further downriver, should have been evident from this altitude.

Figure 3. 1998 field survey locations. Numbers refer to site descriptive data in Appendix A. Green dots indicate SAV found. Brown dots indicate no SAV found.


1998 SAV Field Survey Results
SAV Present
No SAV Found
HENRICO
CHESTERFIELD
CHARLES CITY
JAMES CITY
PRINCE GEORGE
SURRY
ISLE OF WIGHT
Chickahominy River
Appomattox River
James River
Warwick River
NEWPORT NEWS
HAMPTON
Hampton River
Pagan River
Lanesmond River
N
W
E
S
0 5 10 Km
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Chickahominy Region

In the Chickahominy region of the James numerous SAV beds were found (Fig. 3). These were dominated by two species including coontail and common naiad (*Najas minor*) in approximately equal abundances, although some small patches of common elodea were also found. The SAV vegetation typically was found growing along the edge of an emergent marsh shoreline at water depths of less than 1 m. Occasionally the SAV formed large beds across shallow, muddy flats. The distribution paralleled that observed during a similar ground survey conducted in 1978 by K.A. Moore (Orth et al. 1979) although, qualitatively, the abundance of SAV in 1998 seemed greater. Both coontail and common naiad have little below ground structure and, therefore, they were most common in sheltered areas. Although several large beds were found along the main channel of the lower Chickahominy, the SAV vegetation typically decreased at the mouth of a creek and only a few drifting patches were observed in the mainstem of the James. SAV was also found in small, isolated patches within Grays, Powhatan, College, and Lower Chippokes creeks. Quantitative determination of the abundance of SAV will be determined from high altitude photography taken during the summer of 1998 and will be published in report form (eg. Orth et al. unpubl.). This region of the James is characterized as a transition zone between fresh and salt water. Although the SAV species found here can tolerate some salinity (Stevenson and Confer 1978) their occurrence with the creeks suggests that their exposure to salt water is slight. During the surveys in this region salinities were generally below detection (<1 psu) in the sites where SAV was found.

Lower James

Few SAV beds were found from Jamestown Island to the James River bridge (Fig. 3). Only a few small beds of coontail were located in Mill and College Creeks, which are situated along the river's north shoreline. The south shoreline of James from Hog Island to Willoughby Spit was not surveyed. Small, scattered beds of eelgrass were located along the north shoreline from Newport News Point to the Hampton River.

Historical Survey

A variety of historical photographic images of the James River were located, however the quality of the imagery for determination of SAV abundance ranged from good to poor. In general, a number of criteria must be met for acquisition of aerial photographs which are optimum for delineation of estuarine SAV (eg. Orth and Moore 1983b, Orth et al., 1998). These address tidal stage, plant growth stage, sun elevation, water and atmospheric transparency, wind, sensor operation, flight line plotting and film type. Most imagery used for historical SAV analyses has been obtained for other purposes, usually land use or farming analyses, and therefore, while criteria for atmospheric conditions are usually met (eg. sun elevation, atmospheric transparency, etc.), those important for SAV delineation (eg. tidal stage, water transparency, plant growth stage) may not be met. In addition, while standard black and white, and color photographs are useful for SAV delineation (Orth et al. 1984) other film types such as infrared or color infrared photography, which effectively delineations upland vegetation, are less useful in delineating submerged vegetation because of the rapid absorption of the infrared wavelengths of sunlight in water.

In general, the most useful historical photography found in this study for delineation of SAV in the James River came from USDA and VDOT. This photography acquired for land use and transportation purposes was primarily black and white format at scales of approximately 1:20,000. The earliest photography is from USDA overflights conducted during 1936 and 1937.

Six regions along the James that were found to have historical evidence of SAV (either photographic or ground survey data) are hightlighted in summary maps presented in this report (Figs. 4-9). Where SAV was identified on more than one year of photography a layered, composite coverage is displayed. SAV ground survey locations identifying the presence/absence of SAV during the 1998 surveys are also presented on each figure. A detailed summary of the historical photographic and other data sources which were reviewed in this study are presented by individual county shoreline and year in Appendix B.

Hopewell Region

A total of 915 hectares (2260 acres) of historical SAV were identified within this freshwater, tidal region of the James River (Fig. 4). These beds mark the most upriver limits of SAV which could be identified on the historical photographs. Similar coverages were found in both aerial photographs taken for USDA in April 1937 and in USC&GS hydrographic surveys made from April to September of 1944. No SAV were evident in historical photography dating from approximately 1959 to the present (Appendix B) for this entire region. In addition, various ground surveys conducted from 1975 to 1978 and in 1998 reported no significant SAV beds in this region. These results suggest that the large areas of SAV declined in this region sometime between the late 1940s and late 1950s, and only a few scattered beds within several small tributary creeks remain.

Upper Chippokes Creek Region

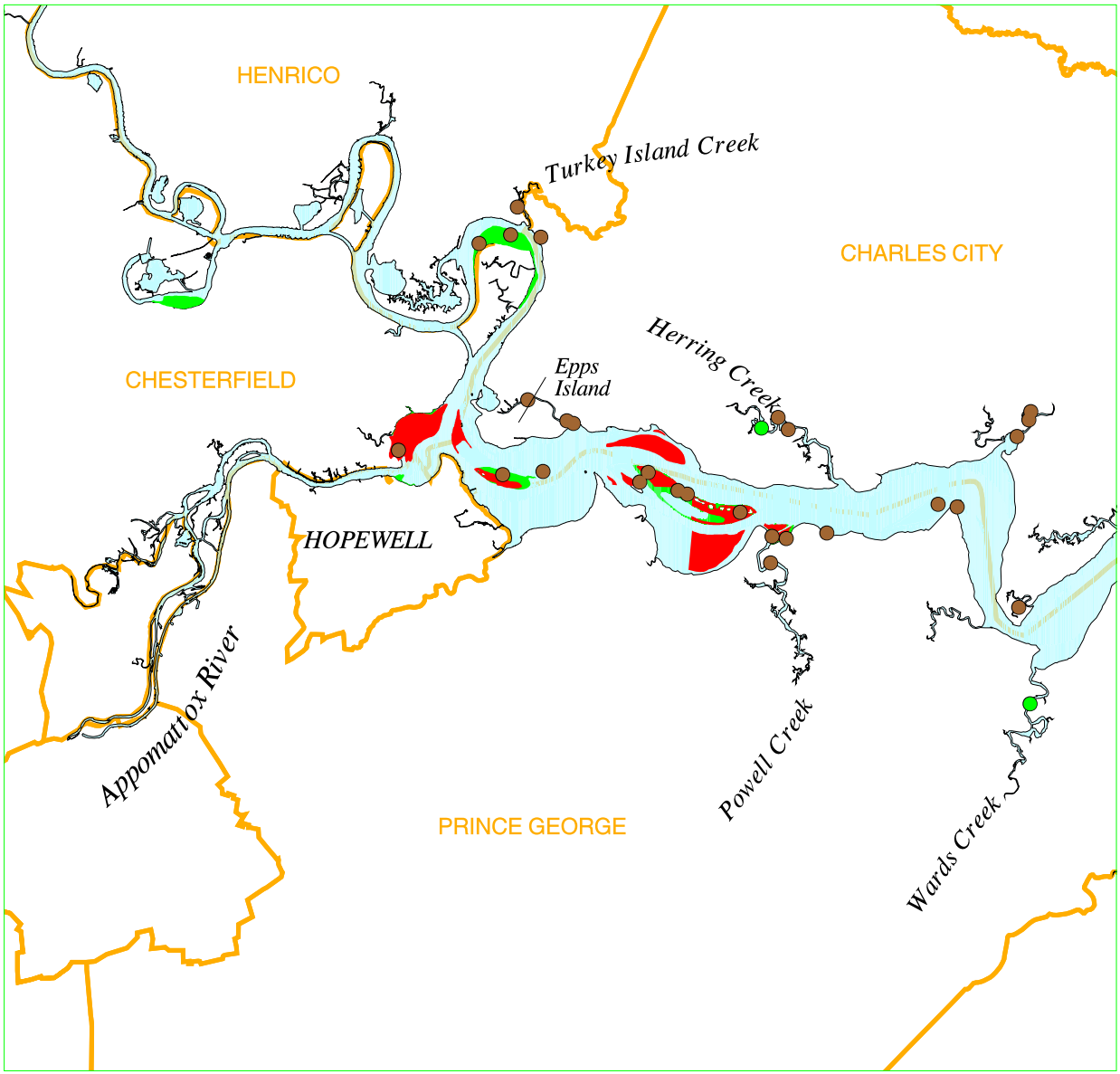
Upper Chippokes Creek, which forms the border between Prince George and Surry counties appears to have retained at least some SAV nearly continuously from 1937 to the present (Fig. 5). Currently the SAV consists of fringing beds of coontail and common naiad which total approximately 39 hectares (96 acres). The SAV vegetation has typically occurred along the shallow edges of the creek channel as well as within one larger shallow embayment near the head of the creek. No SAV was evident along the shoreline of the James either upstream or down stream of the confluence of the creek and the river.

Chickahominy River Region

Extensive SAV was reported within the Chickahominy River in both aerial and surface surveys conducted in 1978 and again in 1998 (Fig. 6). The SAV abundance reported in 1978 (Orth el al. 1979) was 91 hectares (225 acres). No SAV was evident in historical photography taken at various times from 1937 to 1979 (Appendix B). However, because of the small size of the SAV beds, which typically have been found fringing along the various marsh channels and small creeks in the system, it is very possible that SAV present prior to 1978 was simply not

Figure 4. Historical distribution of SAV for the Hopewell Region of the James River by year identified. Dots indicate the 1998 field survey locations and whether SAV were present (green) or not present (brown).

Hopewell Region
(Combined Area: 915 Hectares)



1937 Aerial Photography

1948 USC&GS Survey

No SAV Found (1998)

SAV Present (1998)

N
W E
S

0 1 2 3 4 5 Km

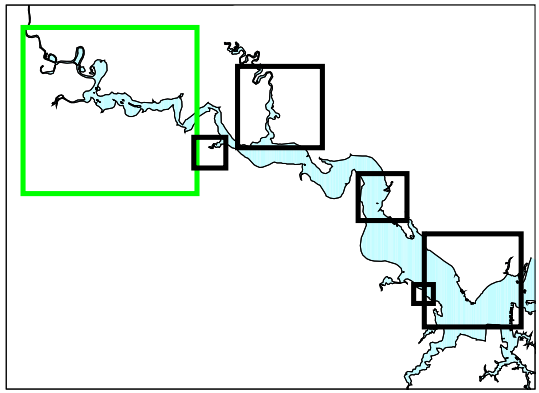


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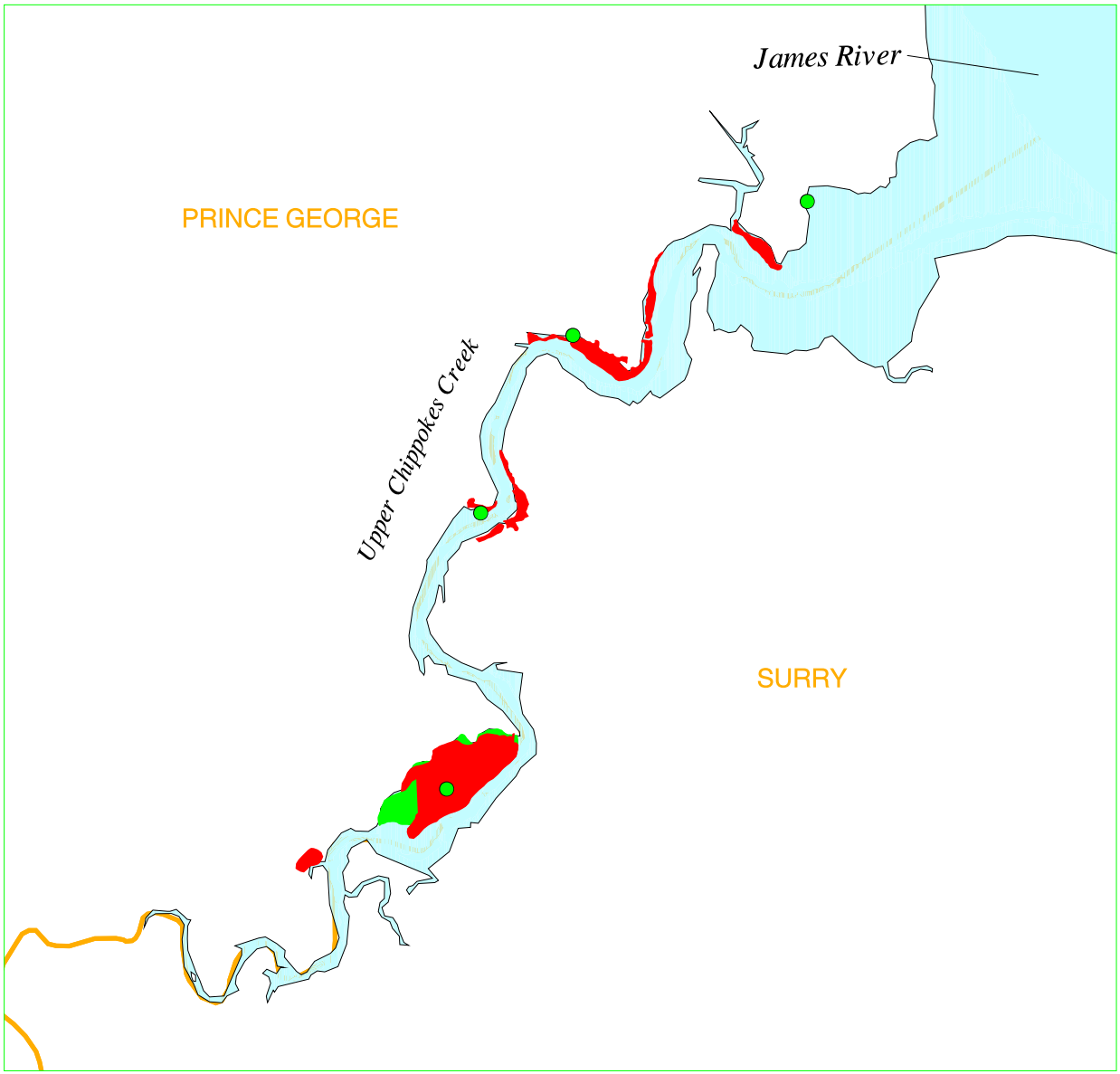
Figure 5. Historical distribution of SAV for the Upper Chippokes Creek Region of the James River by year identified. Dots indicate the 1998 field survey locations and whether SAV were present (green) or not present (brown).

Upper Chippokes Creek Region
(Combined Area: 39 Hectares)



1937, 1947, 1948, and 1954 Aerial Photography

1948 USC&GS Survey

No SAV Found (1998)

SAV Present (1998)

N
W E
S

0 0.5 1 1.5 Km

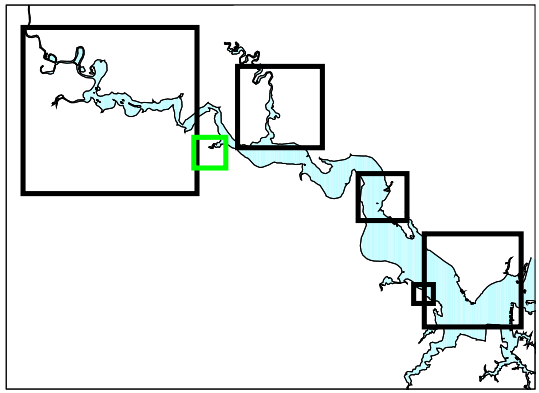


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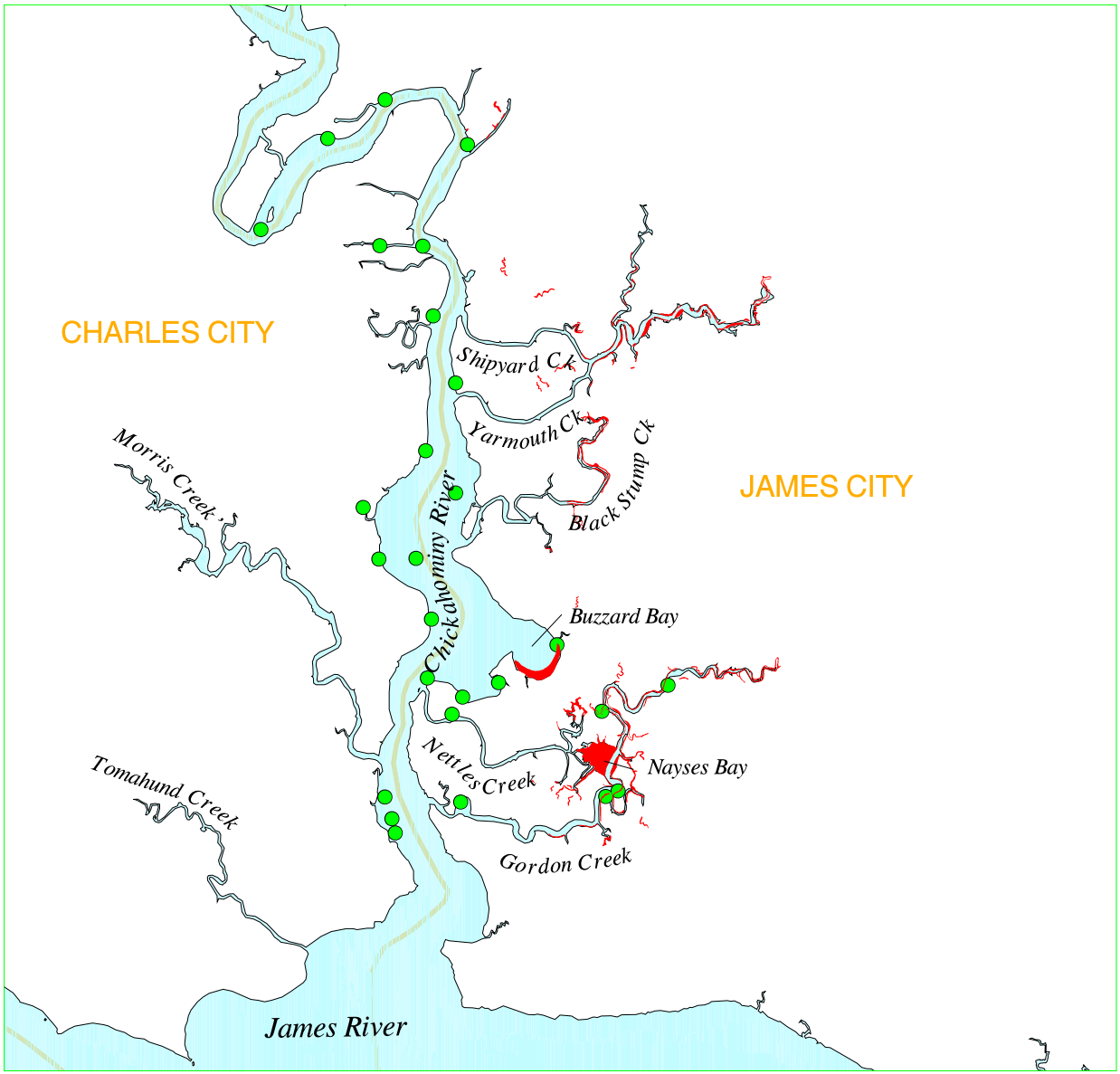
Figure 6. Historical distribution of SAV for the Chickahominy River Region of the James River by year identified. Dots indicate the 1998 field survey locations and whether SAV were present (green) or not present (brown).

Chickahominy River Region
(Combined Area: 91 Hectares)



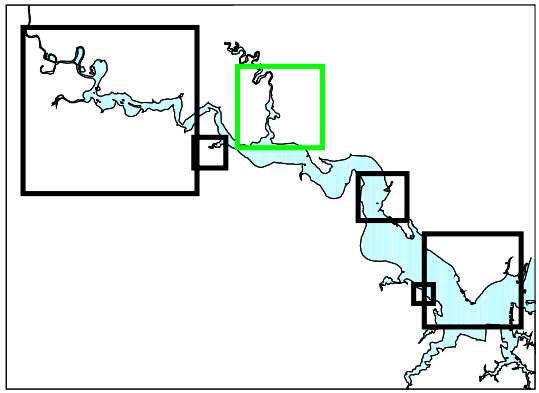
1978 VIMS Aerial Survey

No SAV Found (1998)

SAV Present (1998)

N
W E
S

0 1 2 3 4 Km



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detectable. The photography which was flown in 1978 was specifically conducted under the criteria designed to maximize the acquisition of any SAV signatures (eg. Orth et al. 1979), while the available historical photography (eg. USDA and VDOT archived photographs) were not taken to satisfy many of these constraints. A diverse assemblage of freshwater SAV species were reported in a 1978 ground survey (Orth et al. 1979) with similar species found in this 1998 survey (Appendix A). Comparison of the ground surveys from these two years suggests that SAV abundance have remained relatively stable or have increased in this region over the past 20 years.

Mulberry Island Region

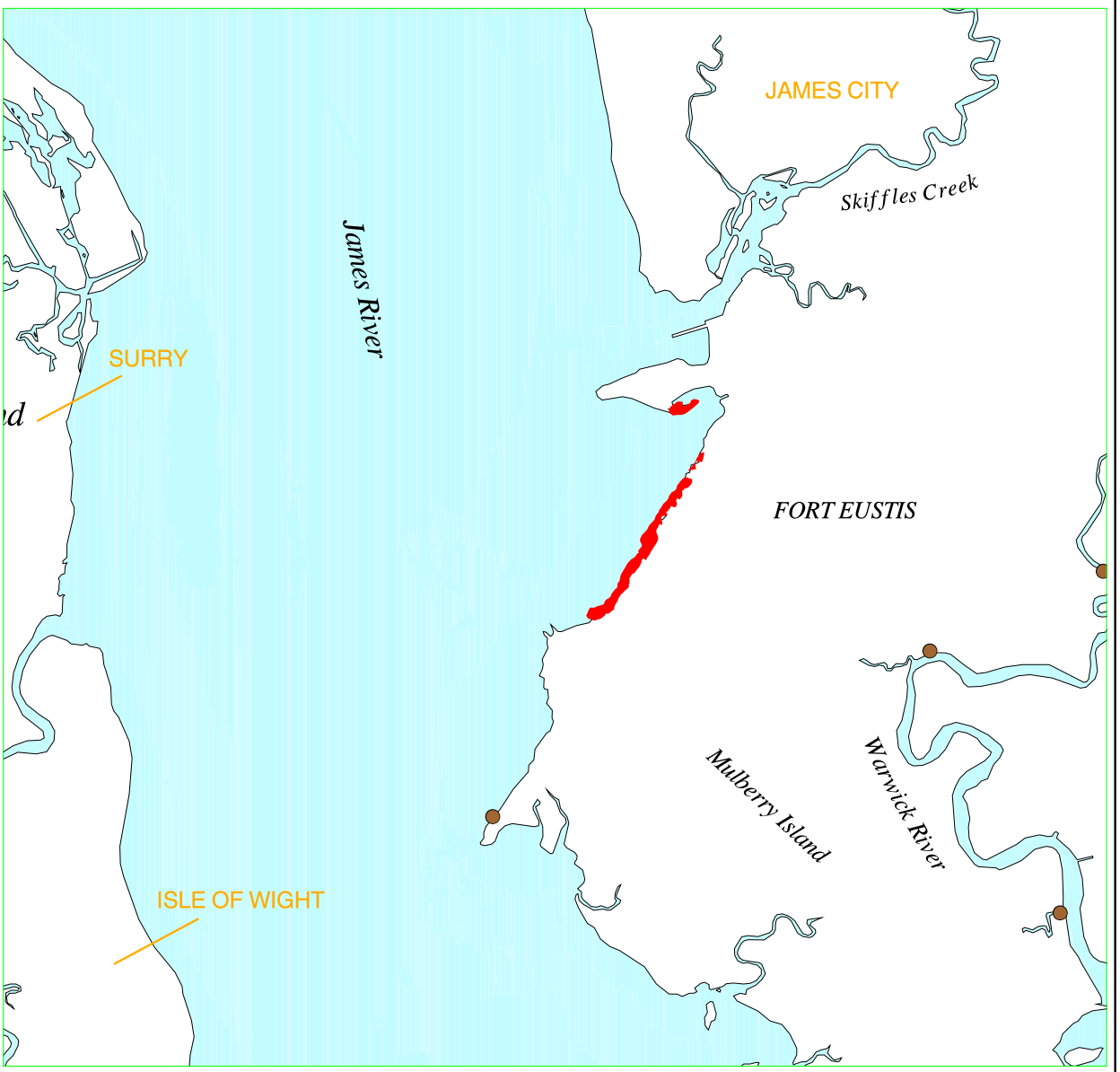
Very distinctive SAV beds totaling 17 hectares (42 acres) were evident fringing along the shoreline of Mulberry Island in aerial photography taken in 1954 (Fig. 7). Only limited historical photographic coverage was found for this area from other years (1937 and 1968) and no SAV beds were evident in these photographs. The 1950s were generally characterized as the period having the greatest abundances of high salinity (eelgrass) SAV beds both in the lower James (see below) as well as for the lower bay in general (Orth et al. 1979). These beds of fringing SAV may therefore represent the most upriver historical distribution of eelgrass populations in the James. No photographic evidence of historical SAV beds were found for the length of the James between this this region and the Chickahominy. However, results of ground surveys over the past 20 years (eg. Orth et al. 1979) suggest that small SAV beds were likely to have been present in small tributary creeks all along this lower section of the James River.

Ragged Island Region

Small fringing beds consisting of approximately 2 hectares (5 acres) of SAV were evident on photography taken by the VDOT in 1954 and 1963 (Fig. 8). The beds outlines were approximately the same each year indicating little net change. The distance upriver of these beds is approximately the same as that observed for beds along the northern shoreline in Newport News,

Figure 7. Historical distribution of SAV for the Mulberry Island Region of the James River by year identified. Dots indicate the 1998 field survey locations and whether SAV were present (green) or not present (brown).

Mulberrry Island Region
(Combined Area: 17 Hectares)



1954 Aerial Photography

No SAV Found (1998)

SAV Present (1998)

N
W E
S

0 0.5 1 1.5 2 Km

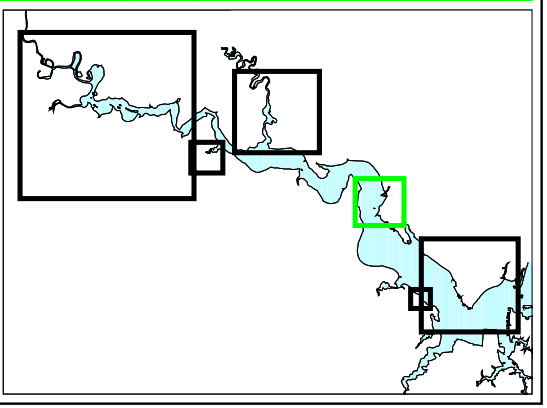


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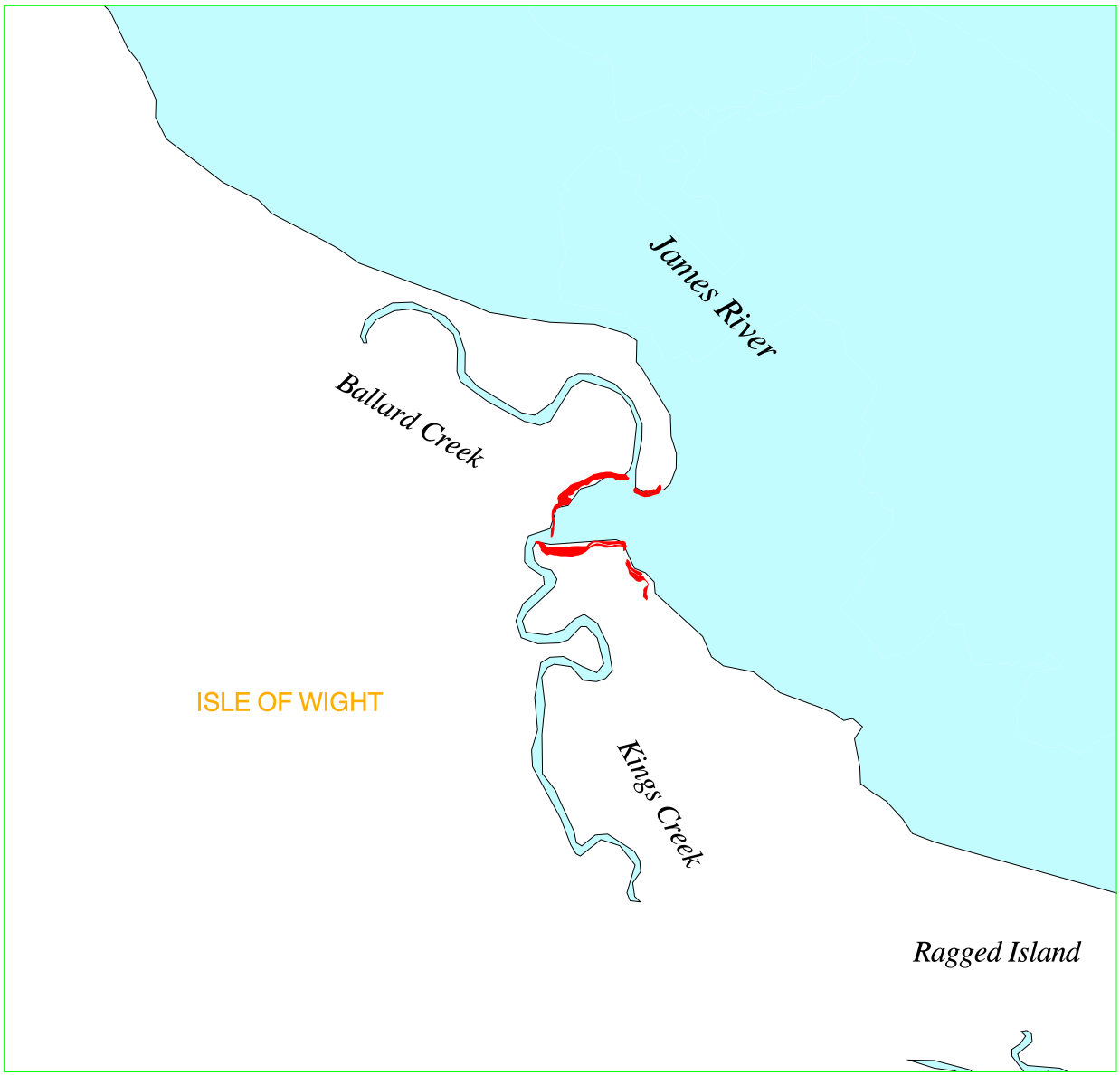
Figure 8. Historical distribution of SAV for the Ragged Island Region of the James River by year identified. Dots indicate the 1998 field survey locations and whether SAV were present (green) or not present (brown).

Ragged Island Region
(Combined Area: 2 Hectares)



1954 and 1963 Aerial Photography

No SAV Found (1998)

SAV Present (1998)

N
W E
S

0 0.5 1 Km

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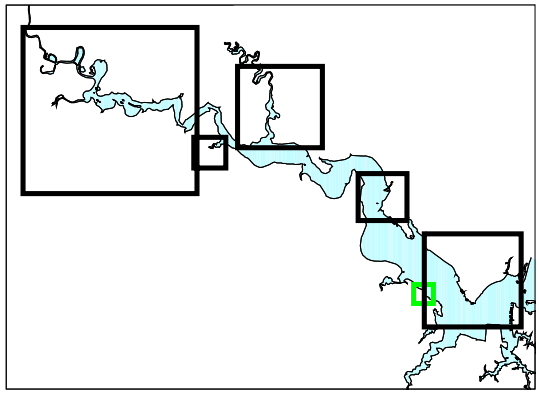


suggesting there may have been a consistent upriver limit of vegetation during this period. Given the typical salinities (>10 psu) in this region, it is likely these SAV beds were dominated by eelgrass. No other SAV was evident over the period of 1937 to 1973, when historical photography was available, for the entire southern shoreline of the James and its major tributary creeks and rivers including the Pagan, Nanesmond, Elizabeth as well as Willoughby Bay.

Newport News and Hampton Region

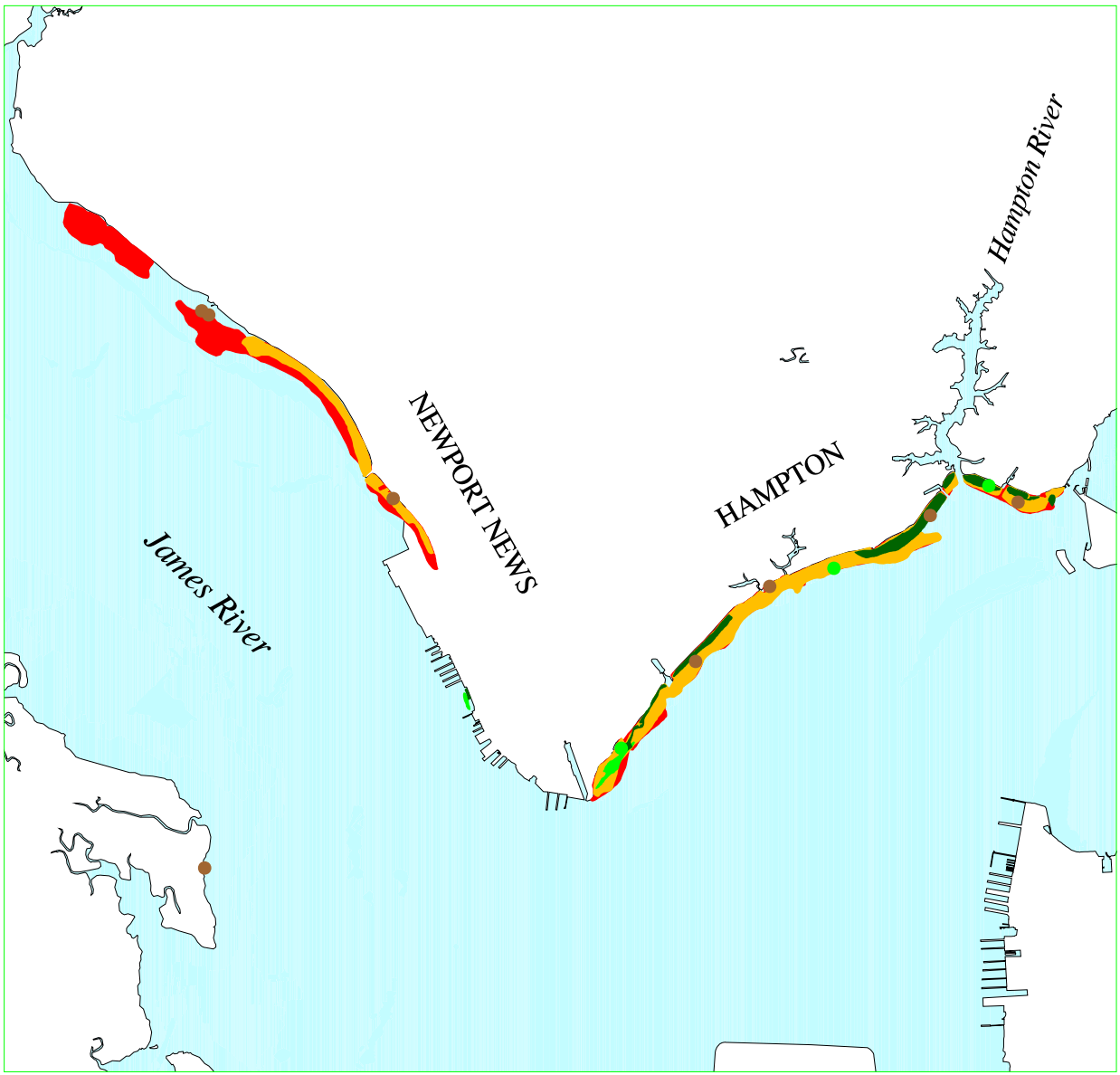
Distinct SAV beds were evident in photography taken from 1953 to 1997 along the north shoreline of the James River in the cities of Newport News and Hampton (Fig. 9). Earlier photography taken in April, 1937, also showed evidence of SAV along this region but plumes of turbid water (possibly due to local winds) obscurred much of the SAV making the imagery poor for accurate SAV delineation. Review of similar 1937 photography for other regions of the lower Chesapeake Bay (ie. Orth et al. 1979) with a similar, high salinity, SAV species (eelgrass) showed that SAV coverage in 1937 was similar in abundance but more patchy than in the 1950s. We believe the relative abundance of SAV in the lower James in the 1930s was likely to be similar to other areas of the lower bay.

One reason for the generally lower abundances of SAV in the high salinity regions of the lower bay and its tributaries in the 1930s compared to the 1940s and 1950s was due to a pandemic decline in the dominant SAV in this region, eelgrass, which occurred along the Atlantic coast of North America, Europe and elsewhere in the early 1930s (Orth and Moore 1984). This decline was not related directly to water quality changes, but to an infestation of a slime mold know as the "wasting disease" (Rasmussen 1977). Certain regions, including many of Virginia's Eastern Shore coastal bays, have still not regrown after this devastation, although this virulent strain of pathogen is not present currently (Burdick et al. 1993). Since the "wasting disease" pathogen was found to be generally less damaging to eelgrass in lower salinity waters, eelgrass in the Chesapeake Bay and its tributaries was less affected than those populations in the higher salinity coastal bays and the distribution in 1937 likely represents some degree of recovery from

Figure 9. Historical distribution of SAV for the Newport News and Hampton Region of the James River by year identified. Dots indicate the 1998 field survey locations and whether SAV were present (green) or not present (brown).

Newport News and Hampton Region

(Combined Area: 584 Hectares)

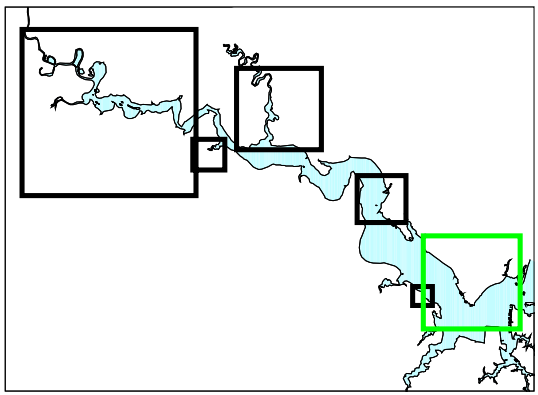


1997 VIMS Aerial Survey
1976 Aerial Photography
1968 Aerial Photography
1953 Aerial Photography

No SAV Found (1998)
SAV Present (1998)

N
W E
S

0 1 2 3 4 Km



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the maximum level of decline in these areas.

SAV reached a maximum observed abundance of approximately 307 hectares (758 acres) in this region in 1953. The distribution then declined to nearly undetectable levels by 1984 but has rebounded since then to approximately 77 hectares (190 acres) by 1997 (Appendix B). This more recent decline of the eelgrass population in the James River observed here from the 1950s to the 1980s (Fig. 9) is likely not to have been caused by a disease organism, but rather by deteriorating water quality conditions aggravated, in part, by storm events (Orth and Moore 1983a). This can be deduced, in part, because the pattern of loss in this tributary is similar to other Virginia tributaries, where studies have shown that the upriver areas where the declines have been greatest are now too enriched with sediments and nutrients to support eelgrass growth (Moore et al. 1996). In addition, the declining abundance of eelgrass evident in the James from 1953 to 1984 shows a distinct trend with upriver areas and the outer edges of the beds declining first. The SAV in this region extended out to the 2 m depth contour in 1953, but today the vegetation is limited to depths of 1m or less. Since background turbidity levels typically are higher with distance upriver in Virginia's tidal tributaries and light decreases exponentially with water depth, any factor that reduces light levels to submersed plants (ie. increased water column turbidity or leaf epiphyte growth) would be expected to have the greatest initial impacts on the most upriver or deepest growing SAV populations.

Recovery of SAV in this region since the mid-1980s suggests that habitat conditions have improved here since that time, and that this pattern and rate of recovery may be typical of what can be expected if conditions were to improve for the entire region. Characteristic circulation patterns of the lower James indicate that bay water inflow should be greatest along this northern shoreline of Hampton Roads. Since bay waters are typically lower in suspended sediments and nutrients than water flowing down the James, it could be expected that habitat conditions for SAV growth should be best, and the initial evidence for SAV recovery and re-colonization of former habitat would be in this region.

Conclusions

Analysis of historical photography and bathometric survey maps indicates that approximately 1645 hectares (4063 acres) of James River bottom have been vegetated with SAV at one time or another between 1937 and 1991 (Table 1). This compares with a Tier I restoration goal of 107 hectares (264 acres) for the River and the most recent published distribution and abundance total of 77 hectares (190 acres) by Orth et al. (1999). Tier I goals have been established as targets for the restoration of SAV to areas previously mapped through regional and baywide aerial survey from 1971 through 1990 (Batiuk et al. 1992). The historical distribution of the SAV determined in the current study including freshwater and low salinity regions was found to be 954 hectares (2356 acres) within the James River and Appomatox River Tidal Fresh (JMSTF and APPTF) Chesapeake Bay Program (CBP) segments, and 293 hectares (724 acres) with the James River Mesohaline (JMSMH) CBP segment. Because of the historical (pre-1971) extent of SAV in these regions was previously unknown no Tier I goals for SAV restoration in these segments have been established. The results presented here could be used to establish goals that reflect the significant historical populations of SAV found in this region of the estuarine system.

Table 1. James River SAV abundance. Historical Area (this study) Tier I Goal (Batiuk et al. 1992). 1997 Mapped Distribution (Orth et al. 1998). nd - not determined.

CBP Segment	Historical Area (1937 - 1991) (hectares)	Tier I Goal (hectares)	1997 Mapped Distribution (hectares)
James River Tidal Fresh (JMSTF)	798	0	0
Appomattox Tidal Fresh (APPTF)	156	0	0
James River Mesohaline (JMSMH)	293	0	1
Chickahominy Oligohaline (CHKOH)	91	91	nd
James River Polyhaline (JMSPH)	307	16	76

Approximately 91 hectares (225 acres) of SAV were found to be historically present in the Oligohaline Chickahominity segment (CHKOH). This area measurement came primarily from a aerial mapping survey conducted in this region by VIMS in 1978. The ground survey conducted for the current study in 1998 suggests that the SAV may have increased in abundance in the Chickahominy compared to 1978. Preliminary analysis of aerial photography that was taken of this segment by VIMS in the summer of 1998 confirms these observation and a four-fold (205 hectare) increase in area has been estimated (Orth et al. unpubl.).

Finally, because few high salinity SAV beds were present in the James River Polyhaline segment (JMSPH) during the period for which the Tier 1 restoration goals were established (1971-1990), a goal of only 16 hectares (40 acres)has been established. Recent regrowth has exceeded this goal. However, it is apparent from the current study's comprehensive analysis of historical SAV distribution in this segment that recovery of SAV is still short of the historical abundance of 307 hectares (758 acres).

Overall, the temporal and spatial patterns of loss of SAV populations in the James River suggest declines occurred first in the tidal freshwater regions of the upper James beginning approximately 50 years ago, and then subsequently in the lower James beginning 30 years ago. Smaller creeks and tributaries including the Chickahominy seemed to have retained some small relic populations, while beds along the mainstem of the river have nearly all disappeared. The limited recovery which has occurred over the past 20 years is centered both in the Chickahominy region and several other tributary creeks in that area as well as the high salinity region of the river along the north shore of Hampton Roads. These observations suggest that water quality and other habitat conditions in these two areas may serve as useful criteria for achieving the goal of restoration of SAV to its historical distribution levels.

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APPENDIX A. 1998 Ground Survey Observations

Nm - common naiad; Cd - coontail; Ec - common elodea; Zm - eelgrass

Station	Latitude	Longitude	DATE	DEPTH (m)	SECCHI (m)	BOTTOM TYPE	SAV PRESENT	SPECIES In order of abundance
1	37.3773	77.2664	10/21/98	0.7	0.30	Mud	No	
2	37.3800	77.2553	10/21/98	0.6	0.30	Mud	No	
3	37.3879	77.2531	10/21/98	0.5	0.30	Mud	No	
4	37.3795	77.2445	10/21/98	0.7	0.30	Mud	No	
5	37.3181	77.2933	10/21/98	0.7	0.25	Mud	No	
6	37.3119	77.2560	10/21/98	0.6	0.40	Mud	No	
7	37.3131	77.2417	10/21/98	0.8	0.35	Mud	No	
8	37.3269	77.2314	10/21/98	0.9	0.25	Mud	No	
9	37.3276	77.2337	10/21/98	0.5	0.30	Mud	No	
10	37.3333	77.2478	10/21/98	0.4	0.25	Mud/Sand	No	
11	37.3107	77.2073	8/18/98	0.7		Mud	No	
12	37.3135	77.2044	8/18/98	0.7		Mud	No	
13	37.3086	77.1937	8/18/98	0.9		Mud	No	
14	37.3076	77.1903	8/18/98	0.8		Sand/gravel	No	
15	37.3028	77.1715	8/18/98	0.8		Mud	No	
16	37.2962	77.1599	8/18/98	1.0		Mud	No	
17	37.2956	77.1549	8/18/98	1.3		Mud	No	
18	37.2886	77.1602	8/18/98	0.9		Organic/Mud	No	
19	37.2975	77.1405	8/18/98	0.8		Mud	No	
20	37.3266	77.1551	10/21/98	0.4	0.40	Mud	No	
21	37.3300	77.1588	10/21/98	0.5	0.40	Mud	No	
22	37.3268	77.1646	10/21/98	0.5	0.36	Mud	Yes	Ec
23	37.3064	77.1012	8/18/98	0.8		Mud/sand	No	
24	37.3058	77.0945	8/18/98	0.8		Organic/Mud	No	

Station	Latitude	Longitude	DATE	DEPTH (m)	SECCHI (m)	BOTTOM TYPE	SAV PRESENT	SPECIES In order of abundance
25	37.3261	77.0738	10/21/98	0.7	0.45	Mud	No	
26	37.3308	77.0698	10/21/98	0.4	0.45	Mud	No	
27	37.3332	77.0691	10/21/98	0.5	0.55	Mud	No	
28	37.2776	77.0719	8/18/98	0.8		Organic/Mud	No	
29	37.2503	77.0719	8/18/98	0.8		Organic/Mud	Yes	Cd
30	37.3010	77.0119	8/18/98	1.3		Organic/Mud	No	
31	37.2932	77.0044	8/18/98	0.7		Organic/Mud	No	
32	37.3073	76.9845	8/18/98	0.8		Mud	Yes	Cd, Ec
33	37.2413	76.9939	8/18/98	1.0		Mud	Yes	Cd
34	37.2340	77.0091	8/18/98	0.8		Mud	Yes	Cd
35	37.2246	77.0149	8/18/98	0.8		Mud	Yes	Cd, Nm
36	37.2101	77.0167	8/18/98	0.8		Organic/Mud	Yes	Cd, Nm
37	37.2661	76.8826	8/17/98	0.8		Organic/Mud	Yes	Nm, Cd
38	37.2681	76.8832	8/17/98	0.8		Organic/Mud	Yes	Nm, Cd
39	37.2711	76.8845	8/17/98	0.9		Organic/Mud	Yes	Nm, Cd
40	37.2706	76.8713	8/17/98	0.7		Mud	Yes	Nm,Cd
41	37.2718	76.8460	8/17/98	1.0		Mud	Yes	Nm,Cd
42	37.2726	76.8439	8/17/98	0.7		Mud	Yes	Nm,Cd
43	37.2783	76.8468	8/17/98	0.8		Mud	Yes	Nm,Cd
44	37.2836	76.8470	8/17/98	0.8		Mud	Yes	Nm,Cd
45	37.2875	76.8355	8/17/98	0.8		Mud	Yes	Nm,Cd
46	37.2828	76.8731	8/17/98	0.8		Mud	Yes	Cd, Nm
47	37.2928	76.8775	8/17/98	1.0		Organic/Mud	Yes	Nm
48	37.2853	76.8713	8/17/98	1.1		Organic/Mud	Yes	Nm, Cd
49	37.2874	76.8652	8/17/98	1.1		Organic/Mud	Yes	Nm, Cd
50	37.29	76.86	8/17/98	0.9		Organic/Mud	Yes	Nm, Cd
51	37.30	76.88	8/17/98	1.0		Mud	Yes	Nm,Cd

Station	Latitude	Longitude	DATE	DEPTH (m)	SECCHI (m)	BOTTOM TYPE	SAV PRESENT	SPECIES In order of abundance
52	37.30	76.88	8/17/98	1.4		Organic/Mud	Yes	Nm,Cd
53	37.30	76.89	8/17/98	1.0		Organic/Mud	Yes	Nm,Cd
54	37.31	76.89	8/17/98	1.5		Organic/Mud	Yes	Nm,Cd
55	37.31	76.87	8/17/98	1.1		Organic/Mud	Yes	Nm, Cd
56	37.32	76.88	8/17/98	1.0		Mud	Yes	Nm, Cd
57	37.33	76.87	8/17/98	1.0		Mud	Yes	Nm,Cd
58	37.34	76.88	8/17/98	1.0		Mud	Yes	Nm, Cd
59	37.35	76.88	8/17/98	0.8		Organic/Mud	Yes	Nm, Cd
60	37.35	76.89	8/17/98	0.8		Organic/Mud	Yes	Nm, Cd
61	37.36	76.87	8/17/98	0.8		Organic/Mud	Yes	Nm, Cd
62	37.37	76.89	8/17/98	0.8		Mud	Yes	Nm, Cd
63	37.36	76.90	8/17/98	0.8		Mud	Yes	Nm, Cd
64	37.35	76.91	8/17/98	0.8		Mud	Yes	Nm, Cd
65	37.19	76.80	10/20/98	0.8	0.35	Mud/shell	Yes	Cd
66	37.18	76.81	10/20/98	0.8	0.50	Mud/clams	Yes	Cd
67	37.22	76.75	10/20/98	0.7	0.55	Mud	Yes	Cd
68	37.22	76.75	10/20/98	0.5	0.50	Organic/Mud	Yes	Cd
69	37.21	76.76	10/20/98	0.9	0.50	Mud	Yes	Cd
70	37.14	76.71	10/20/98	0.6	0.55	Mud	Yes	Cd
71	37.13	76.71	10/20/98	0.5	0.45	Mud	No	
72	37.24	76.71	10/20/98	0.7	0.55	Mud	Yes	Cd
73	37.21	76.64	10/20/98	0.5	0.55	Sand/shell	No	
74	37.13	76.63	10/20/98	1.0	0.65	Sand/shell	No	
75	37.08	76.56	10/20/98	0.6	0.70	Mud	No	
76	37.09	76.55	10/20/98	0.9	0.75	Hard clay	No	
77	37.12	76.57	10/20/98	0.5	0.55	Hard mud	No	
78	37.14	76.58	10/20/98	0.6	0.50	Organic/Mud	No	

Station	Latitude	Longitude	DATE	DEPTH (m)	SECCHI (m)	BOTTOM TYPE	SAV PRESENT	SPECIES In order of abundance
79	37.15	76.57	10/20/98	0.5	0.45	Organic/Mud	No	
80	37.16	76.57	10/20/98	0.3		Organic/Mud	No	
81	37.04	76.49	5/7/98	0.5		Sand	No	
82	37.04	76.49	5/7/98	0.5		Sand	No	
83	37.01	76.45	5/7/98	0.5		Sand	No	
84	36.95	76.49	5/7/98	0.5		Sand	No	
85	36.97	76.41	5/7/98	0.5		Sand	Yes	Zm
86	36.98	76.39	5/7/98	0.5		Sand	No	
87	37.00	76.38	5/7/98	0.5		Sand	No	
88	37.00	76.36	5/26/98	0.5		Sand	Yes	Zm
89	37.01	76.35	5/22/98	0.5		Sand	No	
90	37.01	76.33	5/26/98	0.5		Sand	Yes	Zm
91	37.01	76.33	5/20/98	0.5		Sand	No	

Appendix B. Detailed Listing of Data Sources and Results by County or City (Listed Geographically from Richmond to Hampton)

City of Richmond

1937 - No SAV could be observed in USDA photography taken in April, 1937 in any areas along the river.

1959 - No SAV were evident along the City of Richmond region of the James River in USDA photography taken in July, 1959.

Henrico County

1937 - USDA photography taken in April, 1937, showed no evidence of SAV along the Henrico County side of the James River.

1948 - US CGS hydrographic survey data indicated the presence of SAV as a bottom feature along the James River in April. Descriptions of these beds are included under Chesterfield County.

1959 - No SAV were evident along the Henrico County region of the James in USDA photography taken in July, 1959.

Chesterfield County

1937 - Subaqueous flats across the channel from Farrar Island, adjacent to Turkey Island, within Curles Swamp Creek and at Johnson Creek near Buzzards Point, showed evidence in April, 1937, USDA photography of having SAV. At this time of year freshwater SAV would be expected to have a low standing crop.

1948 - USC&GS bottom bathymetry survey data indicate the presence of SAV as a bottom feature (Figure 3) in very shallow depths at number of the same locations (see above) showing evidence of SAV in 1937.

1959 - No SAV were evident along the Chesterfield County regions of the James or Appomattox River in USDA photography taken in July, 1959.

1960 - No SAV were evident along the Chesterfield County regions of the James or

Appomattox River in USDA photography taken in May, 1960.

1969 - No SAV were evident along the Chesterfield County regions of the James or Appomattox River in USDA photography taken in June, 1969.

Charles City County

1937 - No SAV could be observed in USDA photography taken in April, 1937, along most of the county shoreline including the various tributary creeks and Chickahominy River. A small shallow water flat located off the mouth of Herring Creek appeared similar in appearance to areas of Prince George County photographed on the same overflights, which in 1948 were reported to be vegetated with SAV. No similar confirmation of SAV at this site was found, however.

1948 - USC&GS bottom bathymetry survey data indicate no observations of SAV species along the James River from the mean low water line to the middle of the river.

1960 - No SAV could be observed in USDA photography taken in April, 1960, along the entire county shoreline including the various tributary creeks and Chickahominy River.

1968 - No SAV could be observed in VDOT photography taken in March, 1968, along the entire county shoreline including the various tributary creeks and Chickahominy River.

1969 - No SAV could be observed in USDA photography taken in August, 1969, along the entire county shoreline including the various tributary creeks and Chickahominy River.

1978 - Ground surveys made for the US EPA in July of 1978 (Orth et al. 1979) reported a number of small and moderately sized beds of numerous freshwater species including, *C. demersum*, *N. minor*, *Elodea canadensis* (elodea), *Vallisneria americana* (wild celery), *Naias guadalupensis* and *Naias flexilis* were found in the Charles City County section of the Chickahominy River system. Most of these beds would likely be too small to be evident on 1:20,000 or smaller scale photography.

The City of Hopewell and Prince George County

1937 - USDA photography taken in April, 1937, showed evidence of SAV in the mid-river shallow flats surrounding numerous islands between City Point and Maycocks Point. Also

submerged vegetation appeared to be present growing on shallow flats at the mouth of Powell Creek and just downriver of Powell Creek. No SAV was evident in the Appomattox River. SAV was evident in Upper Chippokes Creek (Fig. 5) which forms the border between Prince George and Surry counties.

1947 - A series of VDOT photographs from April, 1947, showed no SAV along most of the shoreline of the county except for Upper Chippokes Creek (Fig. 5).

1948 - USC&GS bottom bathymetry survey data indicate the presence of SAV as a bottom feature (Figure 3) in very shallow depths at a number of the same locations showing evidence of SAV in 1937. These include the flats surrounding the mid-channel disposal islands and the mouth of Powell Creek. Also an area of SAV was indicated as occurring within Upper Chippokes Creek.

1954 - A series of VDOT photographs from May, 1954, showed no SAV along most of the shoreline of the county except for Upper Chippokes Creek (Fig. 5).

1958 - No SAV were evident along the Hopewell or Prince George County regions of the James or Appomattox River in USDA photography taken in May, 1958. No coverage of Upper Chippokes Creek.

1959 - No SAV were evident along the Hopewell or Prince George County regions of the James or Appomattox River in USDA photography taken in July, 1959. No coverage of Upper Chippokes Creek.

1960 - No SAV were evident along the Hopewell or Prince George County regions of the James or Appomattox River in USDA photography taken in May, 1960. No coverage of Upper Chippokes Creek.

1968 - No SAV were evident along the Hopewell or Prince George County regions of the James or Appomattox River in VDOT photography taken in January, 1968. No coverage of Upper Chippokes Creek.

1969 - No SAV were evident along the Hopewell or Prince George County regions of the James or Appomattox River in USDA photography taken in June, 1969. No coverage of Upper

Chippokes Creek.

James City County

1937 - No SAV could be observed in USDA photography taken in April, 1937, along the entire county shoreline including the various tributary creeks and the Chickahominy River.

1948 - USC&GS bottom bathymetry survey data indicate no observations of SAV species along the James River from the mean low water line to the middle of the river.

1960 - No SAV could be observed in USDA photography taken in April, 1960, along the entire county shoreline including the various tributary creeks and the Chickahominy River.

1970 - No SAV could be observed in USDA photography taken in October 1970, along the entire county shoreline including the various tributary creeks and the Chickahominy River.

1978 - Ground truth surveys made for the US EPA in July of 1978 (Orth et al. 1979) report sparse SAV consisting of *Zannichellia palustris* (horned pond weed) at the head of Skiffes Creek with no SAV observed in downstream areas. Horned pond weed was also reported in the shallows fringing tidal marsh areas at the mouth of Mill Creek. No SAV were found throughout College Creek. *Naias minor* (common naiad) was reported at the head of Powhatan Creek. *Ceratophyllum demersum* (coontail) was found to be growing throughout most of Grays Creek. A number of small and moderately sized beds of numerous freshwater species including, *C. demersum*, *N. minor*, *Elodea canadensis* (common water-weed), *Vallisneria americana* (wild celery), *Naias guadalupensis* and *Naias flexilis* (bushy pondweeds) were found throughout the James City County section of the Chickahominy River system. The larger of these beds were evident on SAV photography taken by VIMS in July, 1978, when seasonal SAV standing crops of these species should be near maximum. The photography was also flown at low tide resulting in maximum exposure of the SAV.

1987 - VDOT photography taken on 4-27-87 showed no visible SAV along the James City County shoreline from the Newport News border to Jamestown Island.

1990 - VDOT photography taken on 4-24-90 showed no visible SAV along the James City

County shoreline from the Newport News border to Jamestown Island.

Surry County

1937 - No SAV were evident along the entire James River shoreline of Surry County in USDA photography taken in April, 1937, however SAV beds were evident within Upper Chippoles Creek as shown in Fig. 5.

1947 - A series of VDOT photographs from April, 1947, showed no SAV along most of the shoreline of the county except for Upper Chippokes Creek (Fig. 5) where fringing beds of SAV were evident within the creek.

1947 - A series of VDOT photographs from April, 1947, showed no SAV along most of the shoreline of the county except for Upper Chippokes Creek (Fig. 5).

1948 - USC&GS bottom bathymetry survey data indicate the presence of SAV as a bottom feature (Figure 3) in very shallow depths within Upper Chippokes Creek.

1954 - A series of VDOT photographs from May, 1954, showed no SAV along most of the shoreline of the county except for Upper Chippokes Creek (Fig. 5).

1968 - No SAV were evident along the entire county shoreline including Upper Chippokes Creek in VDOT photography taken in January, 1968.

Newport News

1937 - SAV were evident along the north shore of the James River downriver from Newport News Point (current site of the Monitor-Merrimac Bridge Tunnel) to the Hampton City line in a series of USDA photographs taken in April, 1937. The imagery has poor contrast and the river water appears to be relatively turbid possibly obscuring some of the SAV. No evidence of SAV was observed along the Newport News shoreline upriver of Newport News Point. However, limited USDA photographic coverage of the shoreline taken in August, 1937, shows SAV growing just downriver from the mouth of the Warwick River in the same vicinity as that evident in subsequent 1953 photography (Fig. 1). SAV in this region of the James River should be dominated by *Zostera marina* (eelgrass) and *Ruppia maritima* (widgeon grass). Widgeon grass

generally reaches its maximum annual standing crop in August, suggesting that this species may have dominated here at this time.

1953 - Abundant SAV were evident along the shoreline from the Hampton City line to the mouth of the Warwick River (Figure 1). No SAV were evident in the vicinity of the Newport News Shipyard, although SAV beds were evidentbeginning in an area just upriver of the shipyard in a shallow water region which was subsequently filled to create additional shipyard property, and continued upriver to the mouth of the Warwick River. No SAV were evident within the Warwick River, or upriver of the Warwick River along the remainder of the Newport News shoreline to the James City County line. Comparison of the channelward limits of SAV growth with established depth contours for the James River indicates that the SAV were growing at least to the one meter (MLLW) depths along most of the shoreline downriver of Newport News Point, but shallower than the one meter contour along the shoreline north of the point. Since SAV require, on average, light levels at approximately 20 to 25 % of surface levels to grow, these differences in depth distributions suggest that there was a generally shallower optical depth upriver of Newport News Point. This may have been due to higher levels of water column light attenuation, leaf surface attenuation by epiphytes, or both.

1958 - VDOT photography taken in September, 1958 shows SAV upriver of Newport News Shipyard in the same generally distribution as evident in 1953. No VDOT photography was found for the shoreline downriver of the shipyard on this date.

1963 - VDOT photography taken in February 1963 show SAV immediately downriver of Newport News Point. This area contained some of the densest SAV apparent in the 1953 photography. Because of the time of year (February) the standing crop of the SAV (especially widgeon grass) should have been near an annual minimum, perhaps only one-tenth or less of summer maximums (Moore et al. 1998). Therefore, the value of this photography for delineating SAV is limited. In contrast to the 1953 photography no SAV were observed upriver of Newport News Point. Again differences may have been due to the time of year.

1968 - VDOT photography from 8-8-68, obtained through the Hampton Roads Planning District Commission revealed dense SAV along the north shoreline of the James River from the City of Hampton border to Newport News Point. Upriver of Newport News Shipbuilding the SAV distribution continued. Here the vegetation appeared somewhat sparser than downriver areas. The SAV was located in the same general vicinity as that observed in photographs from 1953 and 1959 but did not extend as far upriver, nor did it extend as far (or as deep) channelward (Fig. 9).

1974 - Photographs taken by VIMS in the summer of 1974 reveal no evidence of SAV along the Newport News shoreline.

1976 - VDOT photography taken on 3-24-76 showed small scattered patches which may have been SAV near Newport News Point, otherwise no evidence of SAV along any of the Newport News shoreline.

1978 - Ground surveys made for the US EPA (Orth et al. 1979) report sparse SAV consisting of *Zannichellia palustris* (horned pond weed) at the head of the Warwick River with no SAV observed in downstream areas.

1980 - VDOT photography taken on 4-17-80 showed no visible SAV along the Hampton shoreline.

1987 - VDOT photography taken on 4-27-87 showed no visible SAV along the Hampton shoreline.

1984-1987 - Annual SAV mapping reports (Orth et al. 1985, 1986, 1987, 1988) by VIMS indicated no visible SAV along the portion of James River in Newport News. It is possible, however, that beds were present but too small to be evident on the imagery (Orth pers. comm. 1999)

1989-1997 - Annual SAV mapping reports (Orth et al. 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997, 1998) indicated the presence of small beds of SAV along the James River shoreline in Newport News beginning in June, 1996. The bottom coverage of these sparce to

moderately density beds repidly increased from 3.3 hectares in 1996 to 24.5 hectares in 1997.

Isle of Wight County

1937 - No SAV was found in USDA photography taken along most of the county shoreline in April, 1937.

1954 - Small fringing SAV beds observed near the mouth of Kings Creek in VDOT photography taken in October, 1954. No other areas of SAV evident along the remainder of the county shoreline including Lawnes Creek, Pagan River and Jones Creek.

1963 - SAV observed in small, fringing beds at the mouth of Kings Creek. No other SAV observed along the remainder of the county shoreline including Lawnes Creek, Pagan River and Jones Creek.

1973 - No SAV observed along the entire county shoreline, excluding the upper Pagan River in VDOT photography taken in January, 1973.

City of Suffolk

1937 - No SAV observed along the Suffolk shoreline including Chuckatuck Creek and the Nanesmond River in USDA photography taken in April, 1937.

1954 - No SAV found in VDOT photography of the James River shoreline and the lower Chuckatuck and Nanemond River.

1973 - No SAV found in VDOT photography of the James River shoreline generally east of Rt. 17.

City of Hampton

1937 - Characteristic high salinity SAV signatures were evident along the north shore of the James River from the mouth of the Hampton River to the Newport News line in a series of USDA photographs taken in April, 1937. The water appeared to be relatively turbid possibly obscuring some of the SAV. SAV in this region of the James River should be dominated by *Zostera marina* L. (eelgrass) and *Ruppia maritima* (widgeon grass).

1953 - Very dense SAV were evident along the same reach of shoreline in USDA

photography taken in April 1953. These SAV beds are part of a distribution of SAV which occurred along the northern shoreline of the James River to the Warwick River in Newport News (Fig. 9). In Hampton and adjacent areas of Newport News the SAV beds extended channelward to water depths of approximately one meter below mean lowest low water.

1959 - Dense SAV was evident in USDA photography dating from October, 1959 along the north shore of the river in the vicinity of the Newport News/Hampton border. This distribution is very similar to that depicted in the 1953 photography (Fig. 1) although photographic coverage in 1959 was available for only a portion of the shoreline. It suggests, however, that the SAV distribution in 1959 was probably quite similar to 1953.

1963 - No distinct SAV were evident along the James River shoreline in Hampton in VDOT photography taken in February, 1963. The water appeared to be quite turbid, possibly obscuring any SAV present. Some SAV could be seen in adjacent areas in Newport News, suggesting that SAV was probably still present in Hampton. Also, SAV biomass would have been at a minimum in February and only the densest beds would likely be evident at this time of year.

1968 - VDOT photography from 8-8-68, obtained through the Hampton Roads Planning District Commission revealed dense SAV along the north shoreline of the James River. This distribution was very similar to the 1953 and 1959 SAV coverage.

1974 - In photography taken by VIMS in the summer of 1974 only several, small beds were still evident in Hampton. These occurred near the mouth of the Hampton River.

1976 - VDOT photography taken on 3-24-76 showed scattered, small SAV beds along north James River shoreline in the vicinity of earlier 1974 VIMS photography near the mouth of the Hampton River.

1978 - VIMS photography taken to map SAV in June, 1978, showed several small patches of SAV downriver of the mouth of the Hampton River.

1980 - VDOT photography taken on 4-17-80 showed small patches of SAV along the Hampton shoreline just upriver of the Hampton River.

1987 - VDOT photography taken on 4-27-87 showed no visible SAV along the Hampton shoreline.

1984-1987 - Annual SAV mapping reports (Orth et al. 1985, 1986, 1987, 1988) by VIMS indicated no visible SAV along the portion of James River in Hampton. It is likely, however that beds were present but too small to be evident on the imagery

1989-1997 - Annual SAV mapping reports (Orth et al. 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997, 1998) indicated the presence of small beds of SAV along the James River shoreline in Hampton. The bottom coverage of the generally sparce beds steadily increased over this 10 year time period from 0.4 hectares in 1989 to 52.3 hectares in 1997.

Cities of Chesapeake, Portsmouth and Norfolk

1937 - No SAV were observed in USDA photography taken in March, April or July of the James River shoreline, the lower Elizabeth River, and Willoughby Bay.

1954 - No SAV were observed in USDA photography taken of the Elizabeth River in April, 1954.

1968 - No SAV were obseved in VDOT photography taken in July, 1968, of the lower Elizabeth and Lafayette Rivers.

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